STUDIES IN THE USE OF FEEDBLOCKS FOR RUMINANTS

A thesis submitted to the University of Glasgow

for the degree of

DOCTOR OF PHILOSOPHY

In the Faculty of Veterinary Medicine

by PETER, THOMAS, KENDALL

Dept. Animal Husbandry,

University of Glasgow

Veterinary School.

June, 1977.

TABLE OF CONTENTS | Page

Acknowledgements

I wish to express my sincere thanks to my supervisors, Professor R.G. Hemingway and Dr. M.J. Ducker for their interest, help and stimulating criticism during the course of this study and for advice during the preparation of this thesis. I also wish to thank B.O.C.M. Silcock Ltd. for the provision of a Research Scholarship and the Frank Parkinson Agricultural Trust for the provision of a Research Grant which had made this project possible.

I wish also to sincerely thank the feedblock manufacturers, particularly B.O.C.M. - Silcock Ltd., Colborn Group Ltd., and Rumenco Co. Ltd., for their interest, cooperation and readiness to provide the chromic oxide containing and other feedblocks instrumental to the studies contained in this thesis. I am also very grateful to several personnel from these and other companies for their stimulating and informative discussions on the subject of feedblocks and block feeding.

I would also like to sincerely thank the following: Miss M. Young, Mrs. M. Cunningham, Miss A. Finn, Miss P. Wilson and Miss A. Pattison for diligently carrying out the many laboratory analyses; Mr. J. Fraser, Mr. D.G. Gibson, Mr. D.R. Johnston and Mr. M.R. McColl for help with the experimental animals; Mr. A. Waterston in particular and several other farmers for cooperation and the provision of livestock for the measurement of feedblock intakes under practical conditions; Mr. J. Procter of the Department of Statistics, Glasgow University for help with the statistical analysis of Expt 13.2; Mrs. J.C. Mackinnon for the careful and competent typing of this thesis and Mr. A. Finney and his staff for help with the time-lapse photography studies and the other photographic requirements of this thesis.

Summary

Over recent years the 'self-help' feedblock system of giving additional nutrients to ruminant animals has become increasingly popular. This has principally been due to the convenience and potential labour saving attributes of this system of feeding. A series of claimed nutritional advantages for 'self-help' feedblocks have also been proposed which are not possible with traditional 'hand-feeding.' It has been the objective of this thesis to evaluate the validity of these claims and assess the suitability or otherwise of feedblocks in ruminant husbandry.

Two different philosophies of feedblock use were recognised. The original feedblock concept was essentially a low intake product as a supplement for poor quality roughages; the majority of feedblock available in the U.K. fall into this category. Recently, higher intake feedblocks have been developed with formulations more similar to conventional concentrates, these aim to substantially increase ME intake directly via the block ingredients per se, as well as indirectly via increased roughage utilisation. In this thesis they have been referred to as substitute feedblocks. Considerable emphasis has been placed in this thesis on the individual intake of feedblocks and other supplementary foodstuffs using chromic oxide as a faecal marker.

In Section 1 a comparative assessment of individual variation in feedblock intake relative to giving equivalent amounts of DM as concentrates in troughs or cobs spread on the ground was conducted. In virtually all circumstances individual variation in feedblock intake was greater than for 'hand-feeding' for both sheep and cattle, which is the converse of what is often claimed. The use of continuously available feedblocks did not appear to reduce the number of individuals in a group which completely refused to consume feedblocks. In older sheep, dental status appeared to be a major contributory cause to the magnitude of

individual intake variation.

In Section 2 it was shown that feedblocks could not be relied upon to provide a consistent pattern of intake over various periods of time. A wide variety of factors were identified which could potentially contribute to the non-uniformity of total feedblock intake by a group of animals. These could be categorised as factors inherent in the blocks per se, the stock consuming them and other environmental factors, such as climatic variables and managerial influences.

In Section 3, the relationship between feedblock consumption and individual nutrient requirements was examined with respect to protein, energy and magnesium. There was no evidence to suggest a relationship between feedblock intake and physiological need as is sometimes claimed to be the case. Multi-gravid ewes did not consume more feedblock than either single or non-pregnant ewes in late pregnancy. Animals seemed to consume less feedblock when alternative more palatable foods were available e.g. spring grass, and vice versa. This makes the use of feedblocks as carriers of supplementary magnesium during the critical post-turnout periods ineffective because of the very low and unreliable level of intake.

In Section 4 the effect of the feedblocks and their ingredients on the utilisation of roughages, was examined. There did not appear to be any noticeable advantage of giving NPN frequently compared with once daily during a 24-hr period as may occur with feedblocks, in terms of increased voluntary straw intake and digestibility. In other experiments the increase in ME intake from improved roughage utilisation arising through supplementation of roughages with feedblocks was generally small and unlikely to create a plane of nutrition much in excess of the maintenance needs of the animal. One of the major ingrediants of a particular feedblock (EC feed, a residue of the distillery industry) has been widely claimed to enhance roughage utilisation by considerable amounts. This was not found to be the case in this thesis and indeed may have had a negative effect on roughage utilisation.

It is concluded that feedblocks have a useful role to play in animal husbandry, particularly in extensive hill systems of production. However due to their high cost and low energy content relative to alternative compound foodstuffs, their use can seldom be justified where it is possible to give cheaper concentrates, unless considerable saving of labour, results.

INTRODUCTION. BLOCKS AND BLOCK FEEDING

Over the last few years in the United Kingdom and over longer periods in other parts of the world, the provision of supplementary nutrients on a, 'free-access,' basis, to usually ruminant animals has gained in popularity. The term 'free-access,' together with terms such as, 'self-help,' 'self-feed' and 'ad. libitum offer,' infer that the supplement is continually available to the animals and could theoretically be consumed during any part of a 24-hour period. In practice, constraints are applied to limit the intake potential for any group or individual animal by chemical and/or physical means. Essentially, these 'free-access,' supplements fall into two general categories, liquid and solid types. The solid type of supplement is commonly referred to as a block. A block may be defined as a physically solid entity designed to permit unrestricted access for usually, but not exclusively ruminant animals, with the object of providing one or more supplementary constituents to the diet. In the empirical sense, a block may supply only one such constituent, for example common salt.

Many of the basic principles concerned with block feeding are equally applicable to the liquid supplements. Namely, their popularity on a worldwide basis has been largely in response to practical convenience for the farmer. In any extensive or semi-intensive animal production situation, where labour is impossible or expensive any technique which minimises the time spent feeding animals is possibly worthwhile. This is particularly relevant if the labour resources available can be diverted to other management areas. Notwithstanding this, several other advantages have been proposed for the use of 'free-access,' supplements which are intimately concerned with their nutritional value to the ruminant animal, rather than convenience to the stockfeeder. The justification or otherwise of these claimed advantages has been the objective of many of the experiments in this thesis.

CLASSIFICATION OF BLOCKS

Blocks can be formulated in many ways and be intended for use for a variety of purposes. To avoid confusion, the following terminology has been adopted for this thesis. Basically blocks can be classified as follows.

(i) Mineral blocks

The genesis of the block concept stemmed from the desire to provide ruminants with supplementary minerals in a convenient form. The first blocks used were simply aggregates of rock salt, similar to the salt blocks currently available. Other mineral blocks are more sophisticated in that they also supply vitamins, (usually A and D), together with calcium, phosphorus, magnesium and sometimes sulphur. Trace element fortification is also undertaken with emphasis being placed on cobalt, copper, iron, manganese, zinc and sometimes selenium. The major constituent of mineral blocks however, is common salt, which operates to both attract the animals to the block and to regulate intake. These blocks have no protein or energy value and are not feedblocks in the true sense of the word.

(ii) Glucose blocks

These blocks contain predominantly glucose, plus vitamins and minerals and are very palatable. They are principally concerned with the specialised role of providing sheep flocks with energy as glucose and to act as a possible prophylactic against pregnancy toxaemia. No natural and non-protein nitrogen is included in the formulation of the blocks. Strictly, they may be considered as feedblocks but in a very specialised sense.

(iii) Feedblocks

A feedblock makes a material contribution to the diet in the form of energy, protein or both, as well as supplying many of the constituents of mineral blocks. Essentially, there are available two different types of feedblock, representing different philosophies of the role they aim to play in animal production. They are classified here as 'supplement,' and 'substitute,' feedblocks.

a) Supplement feedblocks

The term 'supplement' infers something which forms only a minor fraction of the total diet. According to the U.K. Fertiliser and Feedingstuffs Act (1976) this should be 5% or less. The majority of commercially available feedblocks are designed to fit into the general confines of the supplement category. The original feedblock concept also directed its role to the low intake, supplement situation. The main aim of this type of block is to provide ruminants with nitrogen and certain minerals which are present in very low concentrations in many pastures and roughages.

Supplement feedblocks per se can be divided into two classes; those supplements akin to mineral blocks but also containing non-protein-nitrogen (N P N), usually as urea. As they contain no energy and preformed protein, their classification as feedblocks is rather tenuous. These block types are rarely employed under U.K. conditions, but they are widely used under extensive range and veld situations, such as exist in South Africa. A typical composition of these blocks is as used by Pieterse and De Kock (1962), who used a block containing equal parts of urea, sodium chloride and dicalcium phosphate.

The second class of supplement feedblock is by far the most commonly used in the U.K. These blocks contain energy in the form of cereals, together with either urea and/or vegetable protein as well as most of the vitamins and minerals common to blocks in the mineral range. Additionally some proprietary supplement feedblocks contain distillery by-products. When urea is included it is usually at a level of 30 to 60 g/kg (equivalent to almost 90 to 180 g/kg crude protein equivalent) and a total crude protein content in the feedblock of 140 to 300 g/kg. In other commercially available feedblocks, the protein content is derived from conventional vegetable sources, which together with that from the cereal component gives an overall content of about 150 to 200 g/kg crude protein. Feedblocks for horses fit into this latter category.

Sources of energy are included in supplement feedblocks for a variety of reasons e.g. to act as a carrier for other block ingredients; to supply the animals with additional M.E.; to increase the palatability and intake of the feedblock and to improve the intake and digestibility of poor quality roughages. The energy sources used are highly or completely digestible, such as molasses or starch in the form of cereals. Theoretically the inclusion of small amounts of carbohydrate may improve the utilisation of nitrogen in the supplement by increasing the synthesis of microbial protein which is subsequently digested and utilised by the animal.

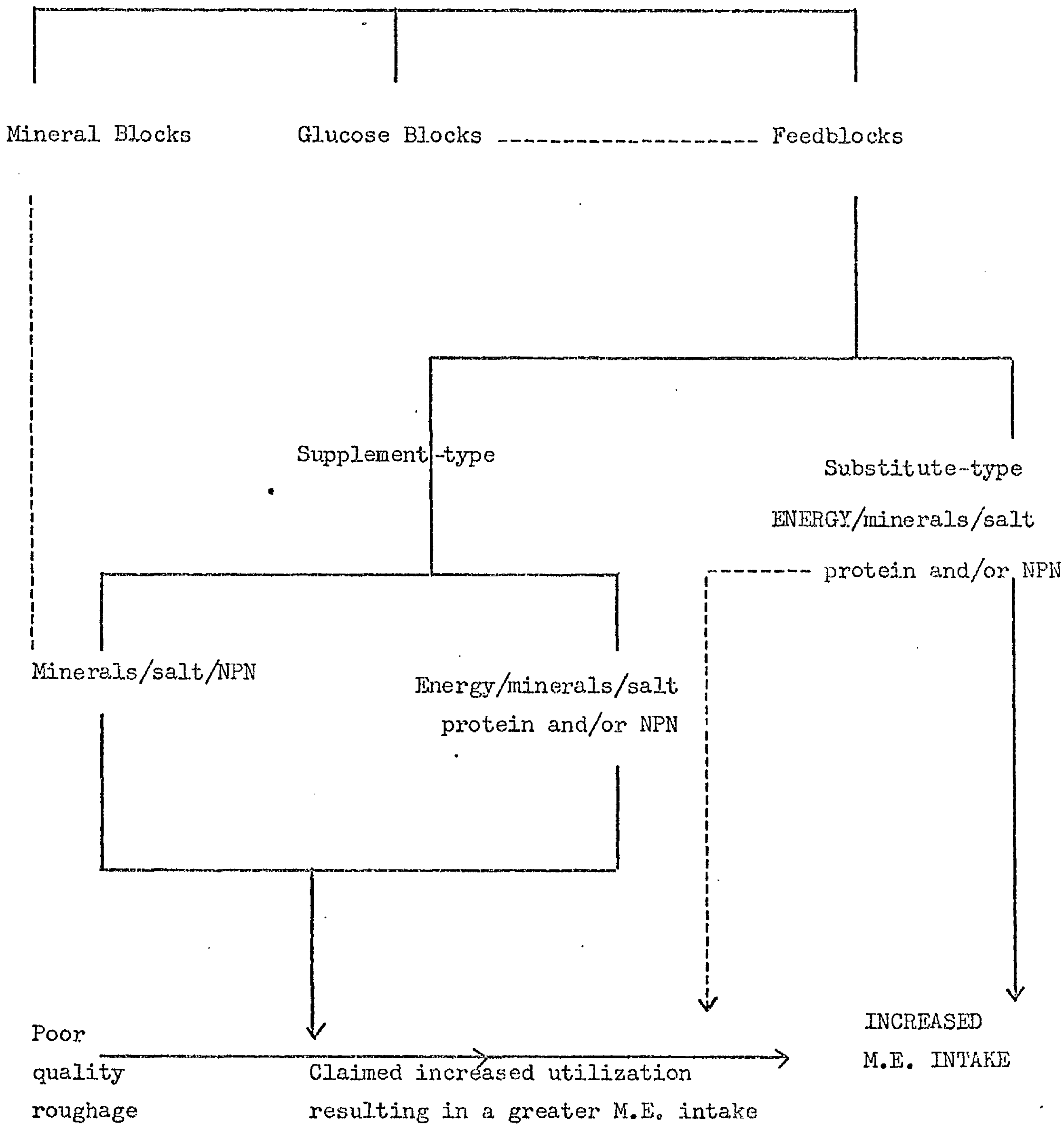
Perhaps the most meaningful definition of supplement feedblocks centres around what can be expected from their use in animal production systems. Their main aim is to create a plane of nutrition for any class of stock at or around the maintenance level from low quality roughage diets, which permit only a sub-maintenance level of nutrition when given alone. However, without further energy inputs (e.g. as cereals), a truly productive situation is not often reached.

b) Substitute feedblocks

The commercial development and introduction of substitute-type feedblocks has occurred only recently in the U.K. These feedblocks allow much higher intake potential for any class of stock, combined with a higher M.E. content.

The resulting effect is that the emphasis on the role of substitute feedblocks is placed mainly on the energy they contribute to the overall diet and less on the increased utilisation of poor quality roughages. Nevertheless, these feedblocks also contain vitamin, mineral and often urea inclusions, in a similar fashion to the supplement feedblock types. Because of the energy contribution to the diet, substitute-type feedblocks have applications in areas where a higher degree of animal performance is required. In this respect they may be likened to concentrate pellets or cobs in a feedblock form.

DIAGRAMATIC CLASSIFICATION OF BLOCK TYPES



METHODS OF BLOCK MANUFACTURE

Blocks vary in shape and weight. The smallest blocks in terms of both weight (6 to 18 kg) and size (rectangular, about 30 x 20 x 20 cms) are usually the mineral/glucose or mineral type blocks. Feedblocks may be either cuboid, rectangular or wheel-like (50 cm in diameter) in shape with weights ranging from 15 to 25 kg. Some cuboid and rectangular feedblocks have bevelled edges and one feedblock type has a longitudinally-directed hole through it.

Four basic manufacturing processes appear to be commonly used, these vary from on the farm manufacture requiring no special equipment to the use of expensive machinery at a permanent production site.

(i) Compressed blocks

The physical integrity and intake of these block types are governed entirely by pressure exerted on the constituent mix imparting hardness. Mineral blocks and some feedblocks are prepared in this way.

(ii) Compression plus the use of binding agents

This process involves a moderate amount of pressure allied to the use of binding agents. Substances employed as binding agents or hardners include, bentonite, lignin sulphonate, molasses and distillery by-products such as dried distillers solubles. One proprietary feedblock commonly used on a worldwide basis, employs a spray dried, distillery residue known variously as E C feed (Ethyl concentrate) or distillers molasses dried solubles. This feedblock is marketed under the trade name 'Rumevite.'* E C feed is an hygroscopic, brown powder with potent binding properties when dampened. Using E C feed as a binder and suitable containers such as halved steel drums, feedblocks are often prepared in South Africa, on the farm where they are to be used. 'Rumevite' is essentially a supplement-type feedblock and its

* Rumenco Co. Ltd., Burton-on-Trent, Derbyshire.

hardness can be varied by altering the proportion of the constituents and/or pressure.

(iii) Chemical setting processes

In this process a chemical reaction between the block constituents is alone used to maintain physical integrity and hardness. The most commonly involved reaction is between calcium oxide or hydroxide and molasses to form calcium sucrosate. The calcium sucrosate is also claimed to restrict intake because of its bitter taste. The molasses inclusion in this process is usually around 300 g/kg of the mix with the hardness being affected by the amount of lime incorporated. This may be between 50 to 70 g/kg in the mix; the greater the level of lime, the harder the resulting block.

This process has the disadvantage of a critically short mixing time before setting commences, resulting in poor quality control as there is often uneven mixing of constituents. It is also very time consuming but has the advantage that it is adaptable to on farm conditions. Also blocks of virtually any shape or weight can be made.

(iv) Extruded blocks

This is the most sophisticated method of block manufacture. The process is somewhat akin to the production of concentrate cubes, in that the blocks are extruded through a die. Very high pressures and steam are used to compress the mixture before extrusion. The main manufacturing advantages of this process are low labour costs and a high rate of block output. However, the initial capital investment in the machinery required is high. The two types of extrusion block making machines at present in use in the U.K. had to be imported from the United States.

A 'Landers' press is used to make the 'Wintawell'* range of

* B O C M - Silcock Ltd., Basingstoke, Hants.

feedblocks, and a "Californian" press is used to make 'Colborn'* blocks. Both ranges of block products produced by these machines fall into the substitute feedblock category.

METHODS EMPLOYED TO ATTEMPT TO CONTROL THE VOLUNTARY CONSUMPTION OF FEEDBLOCKS

The intake of any block depends on a wide variety of factors inherent to the block, the animals allowed access to the block and the environment in which both block and animals are maintained. Although, by definition, blocks are available to stock continuously throughout any 24-hour period, attempts are made by the manufacturers (in the first place) and by the stockman, (in the second place) to restrict the intake to an acceptable level. What infact constitutes an acceptable level is a very arbitary point, but generally the aim as quoted by the manufacturers, is for sheep to consume between 80 to 250 g/head/day and cattle 400 to 1000 g/head/day of supplement and substitute-types respectively. In order to achieve this objective of a controlled intake, a variety of measures are employed which approach the problem from two different angles.

One method of intake control, is that exerted via the block formulation and/or manufacture process whereby constraints on intake are influenced by the chemical and physical nature of the feedblock. Included in this approach is the possible use of containers. Secondly, the feedblock manufacturers attempt to effect an intake control by advocating manipulation of the number of feedblocks available to any

* Colborn Group Ltd., Heanor, Derbyshire.

group of animals, their positioning relative to, particularly, the water supply and their rate of replenishment.

Constraints on intake inherent in the feedblock, resulting in reduced palatability and acceptability are as follows.

(i) Physical Hardness

Physical hardness in a block can basically be attributed to either of two causes. Firstly, by pressure exerted during manufacture, often aided by the use of binding agents such as E.C. feed or bentonite. Secondly, by the use of chemical setting reactions such as the formation of calcium sucrosate and the use of calcium sulphate (gypsum). Some blocks, above all, rely on hardness as the main attribute in limiting voluntary intake. It must be noted, however, that in terms of the animal, the physical hardness of the feedblock surface, at any time, is the most important criterion affecting prehension of block material. Under field conditions the extent to which surface hardness changes in response to climatic variables such as humidity, rainfall and low or high ambient temperature is largely unknown.

(ii) Sodium chloride

Most blocks contain salt in varying amounts depending on block type. Mineral blocks and mineral blocks incorporating N P N alone, usually contain 300 to 400 g salt/kg. Feedblocks invariably contain a lower amount, usually in the range 50 to 200 g/kg. At the 50 g/kg content, the salt may be present to encourage, rather than limit, if the other block ingredients are otherwise unpalatable.

Salt has been widely employed to control intake when supplements are on free access offer. Most of the published data (e.g. for cattle; Pistor, Nesbitt and Cardon (1950); Savage and McIlvain (1951); Nelson, Macvicar, Archer and Meiske (1955); Riggs, Colby and Sells (1953); Hentes, Adams, Moore and Oltjen (1967); Chicco, Shultz, Rias, Plasse and Burguera (1971): for sheep; Weir and Miller (1953), Weir and

Torrell(1953); Meyer and Weir (1954): for cattle and sheep; Meyer, Weir, Ittner and Smith (1955)) refers to the use of salt as an appetite regulator for self-fed concentrate and protein supplements, usually under extensive range conditions, often in arid climates.

The success of salt as an appetite regulator depends primarily on two criteria. Firstly, that the inclusion of salt at a particular level in a supplement should confine, with a reasonable degree of efficiency, the intake of that supplement within the range desired. Secondly, that in achieving this aim no concomitant detrimental effects on animal husbandry or performance should arise.

In general, the published literature tends to validate the first criterion, that salt is an efficient means of regulating the intake of free access concentrate mixes e.g. Riggs et al. (1953), Weir and Torrell(1953). Hentes et al. (1967), concluded that the addition of salt to a supplement lacked efficacy as a fully accurate regulator of intake by cattle because of individual variation.

Availability of water and climatic fluctuations may also affect the use of salt as a regulator but there is no report on these aspects. Savage and McIlvain (1951), found that the amount of salt needed to maintain cottonseed meal consumption for range cattle at about 0·91 kg/head/day was about 1·4 g/kg live weight.

The relevance of these findings to block feeding is largely a matter of conjecture because other block ingredients may modify the effects of the salt. In particular, the overall physical form and hardness of the block may be as important as the salt content in some circumstances. Consequently data which has been obtained from observations of the effects of salt in regulating the intake of concentrate feeds is not likely to be appropriate to block feeds.

Possible toxicity problems associated with high salt intakes apply to all diets incorporating salt. Generally, the effect of salt on the health and function of the animal, has received attention in two different ways. Firstly, the physiological consequences of a high salt intake on the kidney, adrenals and related blood parameters and secondly, the effect of high salt intakes on the digestive processes.

Bolin (1949) reported that lambs receiving a salt drench at the rate of 1 g/kg live weight died within 24 hours. Riggs et al. (1953), reported that histological examination of the kidneys of two cows given 754 g salt/head/day (equivalent to 1·8 g/kg live weight) revealed no harmful effects even after 190 days. They also reported that the absorption of this high salt inclusion was 97·8% compared with 49·1% for cows given only 48·6 g/head/day. The cows given the high salt allowance had a total chloride excretion 11·5 times that of the controls, 98·3% of which was excreted in the urine. The cows were adequately fed otherwise. In the same report, Riggs et al. (1953) outlined details of a trial in which 430 kg cows received 0·43 kg of sodium chloride mixed with 1·0 kg cottonseed meal, under range conditions. The resulting intake of about 1·0 g salt/kg live weight produced periodic scouring which eventually led to the death of one animal. The authors concluded that this was largely due to the conditions of feed and particularly water deprivation which existed under the trial.

Weir and Miller (1953) gave pregnant ewes 39 to 105 g salt/day mixed with cottonseed and recorded that the salt had no effect on kidney and adrenal gland weights for the 4 ewes examined. Only in one instance was the chloride concentration in the blood of the high salt group significantly greater than the controls. Otherwise, there were no significant differences in concentration of Na and K and haematocrit values of the blood. The Na and K concentrations in the milk were however higher.

Meyer et al. (1955) gave various amounts of salt to sheep increasing to 94 and 128 g/kg of diet. There were increased kidney weights but no affects on the adrenals, blood albumen or haematocrit values. Savage and McIlvain (1951), found no difference in live weight gain, blood constituents or general health of steers, 'self-fed' salt-cottonseed mixtures as compared to others 'hand-given' the same amount of cottonseed meal without salt. Meyer and Weir (1954), also reported no effect of high salt intake on live weight gain, blood haematocrits, serum albumen and Na, but blood chloride was increased. Milk chloride content was also increased for the high salt treatments.

In most of these earlier trials which considered the effect of high dietary salt intake on animal health and performance, rumen fill was not measured and as a result an increased water retention on the salt diets could have masked live weight differences between treatments. Animals given high salt diets will drink more water e.g. Riggs et al. (1953); Mosely and Jones (1974). Riggs et al. (1953) found that cows given high salt diets drank considerably more water and excreted 7 times the urine volume of control cattle. Over-wet bedding may be a problem with housed ruminants given large amounts of salt.

The effect of high salt intakes on the digestive efficiency of ruminants has been the subject of several studies e.g. Riggs et al. (1953); Meyer et al. (1955); Nelson et al. (1955); Kromann and Ray (1967); Jackson, Kromann and Ray (1971); Moseley and Jones (1974). The results of these trials indicate that salt may affect digestibility but the literature is divided on whether the response is beneficial or detrimental to the animal. A detailed review will be given later on in this thesis.

(iii) Unpalatability of other block constituents

Urea is probably the most important agent in this respect. Urea is included in many feedblocks as a cheap source of protein at about 45 g/kg of the feedblock, equivalent to about 120 to 130 g crude protein/kg. Higher inclusions are sometimes employed, particularly with the urea/mineral/salt supplement-type feedblocks, which are frequently used under range conditions. In this instance, the urea inclusion may be up to 330 g/kg.

The unpalatable nature of urea has been clearly documented. e.g. Tollet, Swart, Ioset and Templeton (1969) gave concentrate pellets to cattle at range grazing and Ioset (1969) gave supplements individually to cattle receiving a low protein hay. Each measured the proportion of feed refused when different nitrogenous sources were used. Their results were.

	Tollet et al. (1969)		Ioset (1969)	
Constituent	Inclusion rate g/kg	Feed refused %	Inclusion rate g/kg	Feed refused %
Cottonseed or soya bean Meal	708	1·1	530	0·9
Biuret	67	2·5	57	6·3
	100	9·7		
Urea	38	28·5	15	2·7
	56	33·0	25	12·9
			50	55·9

With more than about 20 g urea/kg of supplement considerable unpalatability was recorded. As the urea inclusion in most feedblocks exceeds this amount, urea per se must be a potent agent restricting feedblock intake, unless some other ingredient completely masks its taste.

Similar findings were reported by Lassiter, Grimes, Duncan and Huffman (1958); Van Horn, Foreman and Rodriguez (1967); Holter, Colovos, Davis and Urban (1968); Helmer, Bartley, Deyoe, Meyer and Pfost (1970): with dairy cows offered urea containing concentrate diets.

Decreased concentrate intakes and/or increased consumption times were observed compared to non urea containing concentrates. King, Embry and Emerick (1965) with lambs and Briggs, Gallup, Darlow, Stephens and Kinney (1974) with beef calves also noted the unpalatability of urea containing foods. In some circumstances (e.g. dampness and non-acidic) urea in feeds may decompose to produce ammonia which is also known to reduce palatability.

Among other common feedblock ingredients, calcined magnesite (MgO) is widely regarded as being unpalatable. Most blocks provide supplementary magnesium in this form, in amounts between 20 to 70 g MgO/kg. Apart from its affect on taste some forms of magnesium oxide may increase the hardness of the block.

Other substances included in feedblocks which may have an influence on palatability and intake are the binders or hardners used to maintain physical integrity. These include distillery by-products, lignin sulphonate, calcium sucrosate and bentonite. Generally their effect on feedblock intake in quantitative terms is unknown, but lignin sulphonate and calcium sucrosate (at least) have been shown to be unpalatable in some circumstances.

(iv) Physical restriction of block intake by containers

The advice given by the block manufacturers to the stockfeeder, regarding the use of containers for blocks tends to be both arbitary and inconsistent. Sometimes containers are advocated for use with cattle, but not for sheep. Other factors which appear to influence, when and where block containers are used are ground conditions, whether the stock are housed or not and climatic factors, such as rainfall. In high rainfall areas, a container might accelerate the disintegration of a block by trapping water.

Containers in their simplest form may be an old tyre or a cut-down oil drum (for a wheel-shaped block); other containers are more sophisticated and fit exactly around the block. The latter type are usually, purposely supplied by the manufacturers. In the final analysis, the stockman decides when and where a container is employed, regardless of the manufacturers recommendations.

In most circumstances, the use of containers must influence the level and pattern in which a particular block is consumed. Block consumption may be reduced by containers in two ways. Firstly, by reducing the surface area available to the stock and protecting fragile parts such as the block corners. Secondly, by altering the prehensile mechanism by which animals remove block material, i.e. by encouraging licking and discouraging biting or vice versa. The use of containers may increase block consumption by for example keeping the block more free of mud and/or faecal contamination or by providing a surface to prevent the block moving when it is pushed in chewing or licking by the animal.

The influence of containers, together with the other chemical and physical constraints inherent in any particular block, in controlling intake within a defined and desired level for any group of stock in a given situation, has not been documented. Neither has the influence of managerial measures recommended by the block manufacturers such as the siting of blocks, (especially in relation to the water supply), the number of blocks on offer to any group of stock or per unit of area and their recommended rate of replenishment.

THE COMMERCIAL DEVELOPMENT OF THE USE OF FEEDBLOCKS IN THE UNITED KINGDOM

The feedblock concept originated in South Africa as a means of providing supplementary nutrients to ruminants grazing poor quality veld herbage. Feedblocks were introduced into the United Kingdom in the early 1960's, although mineral blocks had been available much earlier. The use of feedblocks was slow to gain favour and in 1963 an estimate (from within the feedblock manufacturing industry, Stern, 1974), put total annual use at under 1000 tonnes. By 1970 consumption was estimated at 15,000 tonnes increasing rapidly to 40,000 tonnes in 1972. The estimated total feedblock sales in 1975 were 60,000 tonnes (Livestock Farming, October 1976) which indicates some reduction of the rate of expansion.

There seems to be no way of ascertaining what proportion of feedblocks are given to cattle and sheep respectively. It is probably the case that they are used in Britain predominantly in upland areas where trough feeding of compound feeds is difficult to arrange. To put these estimates of the annual use of feedblocks in context, the amount of proprietary sheep foods manufactured in Britain has declined from about 100,000 tonnes/annum in the years 1965 to 1970 to about 70,000 tonnes in 1971 to 1976. (Compound Animal Feedstuffs Manufacturers National Association).

The total quantity of feedblocks used annually may now be subject to considerable fluctuation, depending on amongst other factors the severity and extent of the winter or dryness of the summer. Both a prolonged winter and drought during the summer seem to encourage the use of blocks.

The principal feedblock used in the United Kingdom appears to be "Rumevite" (Rumenco Co. Ltd., Burton-on-Trent) but more recently a wide range of organisations (including major companies in the feeding-stuffs trade such as Colborn Ltd. and B O C M - Silcock Ltd.) have started to produce feedblocks.

The commercial success and demand for feedblocks is reflected in the bewildering array of products now available. There appear to be over 50 apparently different feedblocks marketed by at least 20 commercial organisations. Some may be essentially the same composition as others, differing only in weight, shape and packaging. The position of the purchaser is confusing as very little information is available on composition other than the urea and protein contents.

An essential feature of the feedblock concept is the 'self-help,' aspect, where stock have unlimited access to the supplements. This often demands the inclusion of non-nutritionally useful ingredients to maintain feedblock integrity and to control intake. The proportion these substances take up in the total feedblock formulation varies, but is generally considerable. Therefore, the M E value of feedblocks is invariably far below that for concentrate supplements. Also each feedblock is a physical entity, requiring individual handling and packaging, unlike concentrates which can be handled and packaged in greater bulk. The net effect of these two factors is that feedblocks are more expensive on a dry matter basis and when compared on an M E basis they may be nearly twice as expensive as cereal based compounds.

The presumed convenience and labour saving attributes of block feeding have contributed enormously to the popularity of feedblocks. However, several nutritional and management interlinked benefits accruing from the use of feedblocks have been extensively proposed. The origin of these claimed benefits has largely, but not exclusively arisen from sources inside the block manufacturing organisations. Published data obtained under controlled, experimental conditions on the validity of these claims are not largely available.

A REVIEW OF THE PUBLISHED LITERATURE ON FEEDBLOCKS

The published literature on the principles of block feeding and the validity of the resulting claimed advantages of block feeding systems, is noteworthy for its scarcity. Very few communications relate to the use of feedblocks under U.K. conditions.

Most of the published experiments refer to extensive range or veld conditions where the most frequently used criterion of animal performance has been live-weight change. The majority of the results indicate a reduction in the live-weight loss or at the most a small promotion of gain, when N P N containing feedblock supplements have been offered to ruminants under dry, range conditions. This response to feedblock supplementation seems to be inversely related to roughage quality. However, in many experiments the exact reasons for this diminution of live weight loss, appear not to be clearly defined.

Under range or veld conditions, the variables which may contribute to the magnitude of any response from feedblock supplementation, such as roughage quality and quantity and climatic factors, are much more uniform than in the U.K. Therefore, the extrapolation of results generated under range or veld conditions to the U.K. situation must be carried out with extreme caution.

Experiments where the provision of feedblock supplements have reduced the magnitude of live-weight loss for cattle, include the work of Pieterse and De Kock (1962) using 15 month old steers. On poor quality veld grazing, cattle offered block supplements containing equal parts of salt, urea and dicalcium phosphate lost 0·1 kg/day, while cattle receiving only salt and dicalcium phosphate lost significantly more live weight (0·22 kg/day). The block intakes amounted to 112 g/head day and 129 g/head/day respectively. The inclusion of an energy source, in the form of yellow mealie meal at 250 g/kg of the block, resulted in an increased block intake of 286 g/day and a further reduction in live weight loss to 0·04 kg/day.

Pieterse (1961), also reported in the results of two trials under range conditions, a reduced live-weight loss in response to feedblock supplementation. In the first trial, 30-month old cattle were given either a 670 g bonemeal and 330 g salt/kg block or a similar block of composition 500 g bonemeal, 250 g salt and 250 g urea/kg, given with either 280 g molasses or 224 g maize/day.

The cattle receiving no urea lost 0·40 kg/day, those given the urea block plus molasses lost 0·06 kg/day and those given the urea block plus maize lost only 0·03 kg/day. The respective block intakes were 204 g, 182 g and 207 g/day. The urea intake varied from 42 to 56 g/day. In the second trial, yearling cattle were offered a salt/bonemeal block as before or the urea/salt/bonemeal block. When no urea was given, block intake was 246 g/day and live-weight loss was 0·33 kg/day. Those supplemented with urea consumed 216 g/day and maintained live weight.

Beames (1963) examined the effect of supplementing cattle of two age groups under yarded conditions with a feedblock containing 400 g urea, 100 g molasses, 475 g salt and 25 g trisodium phosphate/kg. The cattle also received hay (35 g C P /kg) ad libitum. The provision of supplementary N P N in the feedblock increased hay intakes of 14 and 26-month old cattle by 46 and 29% respectively. The older cattle lost an average 0.25 kg/day over a 161 day period on hay alone but only 0·09 kg/day for the feedblock supplemented group. The younger cattle lost 0·14 kg/day over an 85 day period on hay alone but gained 0·13 kg/day for the feedblock supplemented cattle. The interday feedblock intakes varied greatly, particularly for the older cattle. During the initial week of supplementation, the mean feedblock intake was 53 g/day compared with 370 g/day for the second week (130 g urea/day). There was less variation in block intake for the younger cattle being within the range 137 to 193 g/day.

Burns (1965), conducted trials with feedblocks containing 300 g urea/kg, offered to 10-month old, shorthorn cattle under range conditions. These cattle consumed 94 g/day of the feedblock and lost an average of 0·08 kg/day compared with animals receiving no block, which lost 0·17 kg/day. In a second trial with 7-month old cattle, the provision of supplementary nitrogen in a feedblock resulted in a live-weight loss of 0.04 kg/day as compared with 0·12 kg/day for supplemented animals. The mean feedblock intake in this second trial was 60 g/day.

Bishop and Grobler (1971) offered separate groups of yearling steers grazing veld during winter, feedblocks containing either (a) fish meal or (b) urea and 300 g maize meal/kg or (c) a control block containing only bone flour and salt. There was no difference in live-weight loss (4 kg) over the experimental period for the cattle given the nitrogen containing feedblocks but a significantly greater live-weight loss was observed (35 kg) for cattle offered the control block.

Reyneke (1971) conducted a trial using 3 groups of 10 Friesland cows on veld grazing (C P 24 to 44 g/kg) over 3 successive winters. The following treatments were given which included the provision of block supplements (a) a block containing equal parts of salt, dicalcium phosphate urea and yellow maize, (b) a similar block plus sufficient maize silage (6·8 kg) to supply 50% of the N requirements for maintenance, (c) a block containing 235 g yellow maize meal, 235 g dicalcium phosphate, 235 g volatile fatty acid sodium salts, 235 g urea and 59 g salt/kg. The respective mean block intakes were 290, 266 and 317 g/day. A further group of cows were given a block (d) containing equal parts salt and dicalcium phosphate and no N P N These cows lost 22% live weight over the winter periods. The cows given treatment (a) lost significantly more live weight, (10%) and (4%) for non-gestating and pregnant animals, respectively, than those on treatments (b) or (c). Three further groups of 10 cows were wintered in pens and received sufficient maize silage to satisfy the N requirements for maintenance, plus one of the following (e) a similar block to (d), (f) a block containing equal parts dicalcium phosphate, salt and urea, (g) a similar block to (c). The respective mean block intakes were 17, 142 and 259 g/day. The live-weight loss (3%) did not differ significantly for the penned cows.

Other workers have shown improved live-weight gains in cattle given feedblocks, e.g. Altona, Rose and Tilley (1960) reported that yearling cattle given poor quality hay with salt blocks containing 300g urea/kg gained 0·28 kg/day more than cattle given salt blocks alone. Similar results were found by Pearce (1973) who under U.K. conditions showed that the live-weight gain of housed, yearling steers given moderate or poor quality hay could be increased by feedblock supplementation. When the cattle were given hay 57 g C P /kg plus a feedblock containing 45 g urea/kg, the live-weight gain was 0·27 kg/day greater than for cattle given the hay alone. The responses when the cattle were given hay containing either 71 g C P /kg or 90 g C P /kg were only 0·08 and 0·03 kg/day respectively. As the magnitude of response to feedblock supplementation was inversely related to roughage quality, any improvement in live-weight gain appeared to be associated with the urea in the block.

In contrast to the work of Pieterse and De Kock (1962), Lesch, Kemm and Van Schalkwyk (1967) found no additional benefit for cattle of providing an energy source additional to N P N in a block. These workers offered hay (30 g C P /kg) ad libitum to 4 groups of 9 month old steers with one of 4 different blocks (a) salt and dicalcium phosphate alone (b) salt and dicalcium phosphate with 250 g maize starch/kg; (c) with 250 g urea/kg or (d) 250 g urea and 250 g maize starch/kg. The intake of urea was between 48 to 53 g/day and this increased hay intakes to the level where cattle received in total 50-60 % more T D N than required for maintenance. The cattle given the salt/D C P block lost 11·8 g N /day, those given the maize meal inclusion lost 1·8 g N./day, those on the urea fortified block gained 2·9 g N /day and the urea and maize supplemented animals gained 2·0 g N /day.

A failure to show any beneficial effect of feedblock supplementation was reported by Jones (1966) using cattle grazing improved pasture. The feedblocks used contained 350 g urea/kg, molasses and salt and consumption was 56 g/day. The crude protein content of the grass selected by the cattle was estimated to be 62·5 g/kg, which largely precludes any major response to N P N When the cattle grazed poorer herbage the block consumption was 64 g/day. There was no interaction between grass quality and supplement, in terms of live-weight loss.

Boling, Bradley and Lovell (1971) also found no response to feedblock supplementation in terms of live-weight gain. These workers gave a variety of supplements including feedblocks to 300 kg, yearling steers on range forage containing 99 g C P and 302 g C F /kg. The feedblocks used contained 370 g C P , 130 g salt, 70 g calcium and 12·5 g phosphorus/kg plus vitamin A and trace elements. Feedblock

Intake was 0.21 kg/day. Again, the failure to obtain a response is in agreement with the accepted view that the voluntary intake of roughages is not increased when their crude protein content is above a particular level.

Pearce and Raven (1973) gave yearling cattle feedblocks containing urea, vegetable protein or combinations thereof. A response to feedblock supplementation in terms of live-weight gain was found but this did not appear to be mediated through the supplementary nitrogen provided, as no increase in hay consumption was recorded. However, the hay offered contained 101 g crude protein/kg which is adequate per se to satisfy nitrogen requirements for rumen metabolism. The magnitude of the response increased as the urea content of the feedblock decreased and vegetable protein increased. In this experiment the response to feedblock supplementation seemed to be via the extra dietary energy afforded.

The effect of feedblock supplementation on the live-weight changes of sheep has also been the subject of several investigations, again mainly under extensive range conditions. For instance Beames and Morris (1965) studied the effect of feedblock supplementation on the performance of Merino wethers. The sheep were given hay ad libitum containing 35 g crude protein/kg over a 16 week period. One group of 20 wethers received no supplement, a second received a block containing 500 g salt, 100 g molasses, 50 g pollards and 350 g urea/kg; a third group were offered a similar block but with only 200 g urea/kg; a fourth group received a block containing no supplementary energy in the form of molasses or pollards. Supplementary nitrogen increased the intake of hay. Those sheep receiving no supplement lost 20% of their initial live weight, the sheep given the feedblocks containing extra energy lost significantly less (10%), while the sheep given the feedblock with no energy lost 12% of their live weight.

Buchanan and Shone (1966) conducted two experiments with groups of 18 month old Merino ewes given veld hay (50 g C P and 407 g C F / kg) ad libitum. In the first experiment over a 52-day period the sheep were given feedblocks containing either (a) urea, maize, salt and distillers molasses dried solubles (b) urea, maize and vegetable protein; or (c) salt and dicalcium phosphate. The block intakes were 95, 191 and 21 g/day respectively. There was no significant difference in hay intake between the groups. The live-weight losses of 9, 0 and 44 g/day (a), (b) and (c) respectively showed that inclusion of supplementary nitrogen was of significant benefit.

In a following 52 day period, the sheep were given either 120 g/day of each of the same nitrogen supplemented blocks or 20 g/day of those composed of only salt and dicalcium phosphate but the blocks were broken into pieces before feeding. Again the sheep given the supplementary nitrogen lost significantly less live weight.

In the second experiment, groups of 6 sheep were given hay and water either or alone with (a), a molasses meal concentrate at a fixed daily allocation of 227 g/head/day; or (b) a urea-salt feedblock allowing free access; or (c) a molasses-meal concentrate containing 220 g salt/kg allowing free access; or (d) a urea-molasses solution on free access offer. The feedblock intake was only 18 g/head/day while that of the 'free-access' concentrate was 9 g/head/day. The intake from the liquid amounted to 200 g/head/day. There was no significant difference in hay intake between the treatments.

The reasons for the reduced live-weight loss observed in the first experiment, when the sheep were given a feedblock rather than a mineral block are confounded in several ways. Firstly, it is not possible to differentiate between the response to energy and nitrogen in terms of live-weight change. No increase in hay intake resulted from the provision of extra nitrogen therefore it appears likely that most of the reduced live-weight loss was due to the energy supplied by the maize and vegetable protein. The small numbers of sheep per group (6 sheep) also limits the confidence that can be placed on the data.

Van Niekerk, Basson and Mulder (1967) used a feedblock, containing 190 g urea and 120 g molasses/kg plus bonemeal and salt, as a supplement for both ewes and wethers under conditions of drought. Similar sheep were given a control block containing 650 g bonemeal and 350 g salt/kg. In addition all the sheep received 259 g/head/day of yellow maize or the same total allocation once or twice weekly. All the wethers gained and most of the ewes lost live weight. The mean daily intake of urea was 4 g which had no significant effect on live weight. Giving maize every day appeared to be of benefit but did not appear to interact with the feeding of urea.

Creswell, Gill and Fraser (1968) examined the effect of giving a proprietary feedblock (Rumevite) to Herdwick wethers given hay (60 g C P and 340 g C F /kg) ad libitum. Rumevite contains urea, cereals, salt and E.C. feed (distillers molasses dried solubles). One group of 21 sheep received no supplement. The second group received feedblock broken into fragments of approximately 2·7 kg. Feedblock intakes increased during the experiment from 35 g/day in weeks 1 to 3 to a mean of 252 g/day in weeks 18 to 21. There was no significant difference in hay intake between the groups but water intake was significantly higher for the feedblock supplemented animals. The feedblock supplemented wethers gained 14 g/day compared with a loss of 22 g/day when no block was given. This difference was highly significant. Wool growth was also significantly improved for the sheep given the feedblock. A microbiological study carried out on two sheep from each treatment, showed higher counts of total free, ruminal bacteria for the sheep given feedblock. There was however, no difference in the rate of digestion of cellulose threads between the treatments. The authors postulated that if the protozoal numbers and rumen volumes in the supplemented and unsupplemented sheep were similar then this increase in bacterial numbers would produce a greater supply of utilisable protein. They also indicated that any protein-concentrate supplement would probably produce a similar result. The small numbers of sheep examined limits the emphasis which can be placed on the data and further work is required.

Unsworth, Lamb and Armstrong (1966) also studied the supplementation of sheep with Rumevite. They reported that in the first of three experiments one ingredient of Rumevite (E C Feed) significantly depressed the dry and organic matter digestibility of the hay which contained 55 g C P and 312 g C F /kg. In two further experiments, only urea which significantly improved nitrogen digestibility, had any effect on roughage utilisation.

Sarif-Sarban and Menke (1970) used Rumevite as a protein source in a concentrate given to sheep in an extensive, arid situation. The formulation of the Rumevite block used was given as 500 g maize, 260 g E C feed, 150 g salt, 60 g urea and 30 g mineral/vitamin mixture/kg. The basal ration given consisted of 200 g barley straw, 280 g D M of wet beet pulp silage and 150 g lucerne hay. Rumevite was included in the concentrate supplement at the level of 210 g/kg, equivalent to 13 g urea/kg in the overall supplement, which also contained barley and beet pulp. The amount of concentrate given varied between 0·5 to 1·5 kg/head/day. A comparison of Rumevite, urea and cottonseed cake as protein sources in the concentrate mix was carried out compared with sheep given no protein supplement in the concentrate mix. There was little difference in live-weight gain for the protein supplemented sheep and about 50 g/day advantage over the sheep receiving no protein supplement. The authors suggest that because the sheep given Rumevite received slightly less energy but did not differ in live-weight gain from the other protein supplemented sheep, an intrinsic benefit of one of the other Rumevite ingredients such as E C feed or trace elements on urea utilisation could have occurred. Equally likely, however, is an increased water retention in the digestive tract due to greater Na intakes resulting from the Rumevite concentrate supplement.(20g Na/kg compared with 6 g Na/kg for the other treatments).

The performance of sheep supplemented with Rumevite blocks under hill conditions was monitored in reports by Roberts (1967) and (1972). Roberts (1967) made available one 25.5 kg block each week to 25 - 30 ewes on upland grazing for an 11 week period before lambing. The resulting lambing percentage averaged over 4 winters was 93 which was claimed to be 23% greater than in previous years. The intake of feedblock was estimated to be 140 g/day although this quantity may have been determined by rationing rather than appetite of the sheep. A comparison with similar ewes, given hay ad libitum plus 140 g/head/day of concentrates and drafted down to in-bye land revealed virtually no difference in ewe performance between the two methods of winter feeding.

A subsequent report Roberts (1972) contained results of trials involving feedblocks of the Rumevite type, either given alone or with molassed sugar beet pulp cubes. No statistical treatment was quoted for any of these experiments and the parameters measured such as ewe live weight, lamb birth and weaning weights and lambing percentages revealed only very small differences between the groups.

The relevance of much of the data accumulated by Roberts, is highly questionable because concomitant management and pasture improvements accompanied the Rumevite block experiments. For instance, large areas of hill were enclosed by fencing and grazing control effected. These are equally likely to have contributed to the increased lambing percentages obtained over the years when blocks were given. In short the calibration of any response accruing from Rumevite supplementation was confounded by the lack of control over the experimental conditions.

The published literature on the usefulness of feedblocks for ruminant animals indicates that under conditions of qualitative and/or quantitative under nutrition, the provision of supplementary nutrients in this form can be effective in reducing live-weight loss or promoting a small live weight gain. N P N (usually as urea) is instrumental to this end. As virtually all the feedblocks used in the experiments reviewed contained appreciable quantities of salt it is possible that some of the improved live-weight status may be due to increased water retention, this may be especially relevant when no salt-containing control blocks were given.

When the quality of the available roughage approaches about 50 to 60 g crude protein/kg, the response to block supplementation in terms of increased roughage utilisation may be very small or non-existent. Any further improvement in live weight appears to be mediated via an additional input of energy commensurate with the amount of gain desired.

OBJECTIVES OF THIS THESIS

There is a distinct lack of critical and impartial information available on the nutritive value of many feedblocks used in the U.K. This applies equally to the nutritional content attributable to the block ingredients per se and also their capacity to improve the intake and to a lesser extent the digestibility of low quality roughages such as cereal straws, poor hay and winter herbage. It has been one of the major objectives of this thesis to attempt to obtain such information.

There appears to be only one report on the effect of weather on feedblock intakes. Ducker and Fraser (1975) reported in small scale trials that the voluntary intake of one proprietary block then available in the U.K. decreased as ambient temperature approached 0°C, which was not necessarily in accord with nutritional needs. However, the effect of snow cover was to increase block intakes. Much more information is required on the effect of weather on feedblock intakes and a second objective of this thesis has been to provide information towards this end.

The influence of a whole variety of managerial practices such as frequency of replacing blocks, number of blocks on offer per group of animals or area of land and the effect of containers on block intake has never been examined. The success or otherwise of the measures taken by the feedblock manufacturers to control feedblock intake in any given situation, such as salt inclusion and block hardness, has never been studied. This information is a necessity for a full understanding of the potential uses of feedblocks in animal production systems.

The individual variation in feedblock consumption seems to have been examined by only three previous workers. Beames (1963) obtained rectal grab samples over 4-day periods. For a group of 14-month steers the mean intake was 320 g/day (range 214 to 361) and the coefficient of individual variation (C V) was 28%. For a group of 25-month steers the mean intake was 430 g/day (range 352 to 468) and (C V) 12·3%.

Beames and Morris (1965) using data obtained by the total collection of faeces over 7 days from 3 groups of 20 wethers recorded mean intakes of 19, 26 and 47 g/day with the range generally from about 5 to 90 g and (C V) from about 39 to 54%.

Pearce and Raven (1973) estimated individual feedblock intake by collecting faeces quantitatively from 6 steers in metabolism cages over a 24-hr period.

For mean intakes of 600, 1560, 2400 and 3250 g/day respectively the corresponding C V values were 79, 34, 19 and 16%. It does not necessarily follow that the reduction in variation noticed with increase in intake is a proper conclusion as four different blocks were used with a progressive replacement of urea (lowest intake) by groundnut (highest intake) which would have altered the palatability of the blocks.

Foot and Russel (1973) used a total collection technique to estimate the individual variation in intake of concentrate pellets given to ewes in troughs in a group situation. The resulting (C V) of individual intake (120 g allowed/head/day) was 36% with individual intakes varying from 14 to 157 g/day.

One of the presumed advantages of block feeding is that because by definition the blocks are on offer continuously, a more uniform supplementation might be effected than is possible when supplementary nutrients are provided in troughs. There is no published work where the supplementation of stock with similar quantities of material by either trough or block methods has been compared. One of the objectives of this thesis has been to evaluate the efficiency of the two forms of supplementation in terms of individual variation under both housed and field conditions. Also to assess the extent to which animals may completely refuse to consume the supplements given. A knowledge of individual intake variation for any feeding system is important and especially for feedblocks which are frequently used as carriers of supplementary magnesium, anthelmintics etc. to counteract the possible effects of animal disease.

Another extensively claimed advantage of block feeding is that stock are able to regulate their block comsumption according to their nutritional requirements in both qualitative and quantitative terms. Alternatively, because of the 'self-help' attributes of blocks, animals are able to exhibit 'nutritional wisdom' and make good dietary deficiencies from block supplements provided. Denton (1961) has shown this to be the case for sodium chloride but the evidence for other dietary constituents is largely to the contrary. It has been one of the objectives of the present study to evaluate the validity of these claims for self-regulation.

Summary of the objectives of this thesis

1. A comparative assessment of individual variation in intake of 'self-help' feedblocks relative to more traditional 'hand-feeding.' Also to determine the proportion of a group of animals which completely refuse to consume feedblocks.

2. To assess what factors influence total group feedblock intake in any given situation and whether feedblocks can be relied upon to give a uniform pattern of intake between days.

3. An evaluation of the validity for claimed 'self-regulation' and 'nutritional-wisdom' aspects of feedblock intake.

4. The assessment of the nutritive value of the feedblocks available in the U.K., both indirectly in terms of effect on roughage utilisation and directly in terms of the block ingredients per se.

MATERIALS AND METHODS

A. FEEDBLOCKS

There is an extensive range of about 50 feedblocks currently available in the U.K. For the purposes of this thesis it was decided to concentrate on three different feedblock types representing different manufacturing techniques and philosophies of use. The feedblocks chosen were manufactured by three independent organisations which have the most important impact with farmers. In adopting this approach, it is not intended to endorse particularly the use of these feedblocks, nor does it necessarily imply criticism of other feedblocks not examined.

The three different feedblock types used have been

(i) Rumevite (Rumenco Co. Ltd., Burton-on-Trent, Derbyshire)

This is a supplement type block principally intended to improve the utilisation of poor quality roughage. Manufacture is by moderate compression with the inclusion of a binding agent. The two types used "Standard" and "High Energy" can be used with both cattle and sheep. The formulation of the "Standard," block was given by Sarif-Sarban and Menke (1970) as 500 g cereal, 260 g EC feed (distillers molasses dried solubles), 150 g salt 60 g urea and 30 g mineral mixture/kg. It is understood that the formulation of the "High Energy" block is similar except for inclusion of salt which in this case is 100 g/kg.

Rumevite feedblocks are wheel-like in shape (50 cm in diameter, 10 cm in depth and weight approximately 22·5 kg). The use of containers such as an old tyre, cut down oil drum or a purpose built tin is recommended for Rumevite feedblocks particularly for cattle and when field conditions are wet.

(ii) Colborn blocks (Colborn Group Ltd., Heanor, Derbyshire)

This is a substitute-type feedblock made by an extrusion process. The two types used have been "Sheep Energy" and "Cattle Block."

Colborn feedblocks are cuboid in shape with chamfered corners, a longitudinally projected hole runs through the block (3·5 cm in diameter). The weight of each Colborn feedblock was 20 kg and dimensions (32 x 23 x 23 cm).

In some circumstances the use of containers is advocated for Colborn feedblocks but no definite recommendation is given.

(iii) Wintawell (B O C M -Silcocks Ltd., Basingstoke, Hampshire)

These are both substitute or supplement-type blocks depending on the particular feeding circumstances. During 1974 in the earlier part of this work the blocks were made by a chemical setting process using no pressure. From 1975 a combination of chemical setting and extrusion processes has been used. Wintawell 290 is a substitute-type block intended for sheep and cattle. Wintawell 291 is a substitute-type block for cattle or a supplement-type block for sheep as the intake by sheep will be lower than with the 290 block.

The intake of Wintawell feedblocks is principally restricted by hardness with the 291 product containing a greater propotion of the hardening agents (Molasses plus lime). Wintawell feedblocks of the earlier type (1974) were rectangular cubes (42 x 29 x 19 cm) and weighed 22·7 kg. The later type Wintawell feedblocks (1976) were somewhat smaller 20 kg being rectangular cubes (34 x 23 x 23 cm). The 1976 Wintawell feedblocks had chamfered edges at the corners.

No container is recommended by the manufacturers for use with any of the Wintawell feedblocks.

Blocks of standard manufacture have been used, the only modification being (where required) the inclusion of chromic oxide at about 2 to 10 g/kg. In some experiments different inclusions of magnesium compounds have been introduced.

The chemical analysis, estimated and derived ME contents of the feedblocks used are given in Table 1. These are the mean compositions

Table 1. Typical analyses of feedblocks used (g/kg DM)

Proprietary feedblock name / Abbreviated name*	Rumevite standard RS	Rumevite high energy RHE	Colborn sheep energy CSE	Colborn cattle CC	Wintawell 290 (1974) W290(74)	Wintawell 290 (1976) W290(76)	Wintawell 291 (1974) W291(74)	Wintawell 291 (1976) W291(76)
CP	243	176	170	204	243	205	226	198
CF	10	16	24	34	38	43	16	34
EE	7	12	60	61	9	23	4	20
NFE	407	463	509	408	505	470	502	496
Ash	333	333	237	293	205	259	252	252
Salt	169	123	145	142	60	58	36	30
GE (MJ)	11.8	11.4	14.5	12.9	12.8	12.7	13.2	13.7
Ca	22.0	24.0	20.1	23.5	56.2	49.4	46.7	51.3
P	2.8	3.8	4.8	3.2	9.7	9.9	10.0	9.3
Mg	17.8	49.2	31.0	39.8	11.9	12.0	24.1	24.0
Estimated ME†	8.9	9.1	11.1	10.2	10.3	10.0	9.9	10.1
Determined ME‡	-	-	10.7	-	7.9	8.3	8.5	9.2
CP from urea	176	90	87	190	170	170	170	170

† Estimated ME (MJ/kg) from Bulletin 33 (Maff et al. 1975) MEF = 0.012 CP + 0.031 EE + 0.005 CF + 0.014 NFE

‡ Determined ME (MJ/kg) from in vivo digestibility trials (DE x 0.81).

* Adopted for use in this thesis.

from numerous samplings. The exact composition of feedblocks used in any experiment where such knowledge is critical to the understanding of the data, will be given when appropriate.

B. ANALYTICAL METHODS

All the analytical methods employed were established procedures which have been in use for several years.

(i) Dry and organic matter contents of foods and faeces

The dry matter (DM) in food and faeces samples was determined by heating 0·5 to 1·0 kg quantities in an oven at 100°C for 36 to 48 hours.

The organic matter (OM) content was determined by placing a crucible and contents in a muffle furnace at 600°C for 4 hours. The consequent loss in weight was recorded as the OM present in the original sample.

(ii) Gross energy

The gross energy of food and faeces samples was measured using a Gallenkamp Ballistic Bomb Calorimeter. Benzoic acid (Thermochemical standard, BDH) was used to calibrate the instrument. The samples and Benzoic acid were pelleted using a die operated by a hydraulic press.

(iii) Total nitrogen

The total nitrogen in foods and faeces was measured by the standard Kjeldahl technique (Kjeldahl 1883). Prior to analysis the samples of faeces were macerated with water and a small amount of toluene according to the technique described by the Grassland Research Institute (C.A.B., 1961).

(iv) Ether extract, crude fibre and ash

The ether extract (EE), crude fibre (CF) and ash contents of foods and faeces were determined by the standard methods (Fertiliser and Feedingstuffs Act 1976).

(v) Chromium

The chromium content of foods and faeces was determined by atomic absorption spectrophotometry according to the method of Williams, David and Iismao (1963). Samples were initially dry ashed.

(vi) Calcium and magnesium

The calcium and magnesium contents of blood and food samples were determined by atomic absorption spectrophotometry.

(vii) Potassium and sodium

The potassium and sodium contents of foods were determined by flame photometry.

(viii) Phosphorus

Phosphorus in foods and faeces was determined by a modification of the method of Cavell (1955). Phosphorus in blood was determined by the method of Fiske and Subbarow (1925).

(ix) Blood urea

The urea content of blood samples was determined by a urease-nesslerization method using the Boehringer Mannheim set of reagents.

(x) Blood ammonia

The determination of ammonia in whole blood was carried out using the micro method of Hutchinson and Labby (1962).

(xi) Blood plasma free fatty acids

The FFA concentration in blood plasma was determined by the colourimetric method of Itaya and Ui (1965).

(xii) Blood ketone bodies

The total blood ketone content was determined by the method of Reid (1960).

C. EXPERIMENTAL TECHNIQUES

I(i) The use of chromic oxide in nutritional studies and the potential sources of error involved therein

In some circumstances the lack of suitable equipment or the particular nature of the trial may make it impractical to measure directly food intake or faeces output or both. An example of this is when animals are fed in a group and measurement of individual feed intake is required. Faecal output can still be measured and if the dry matter intake is known the digestibility of the diet can be determined, providing there is present in the food some substance which is known to be completely indigestible. If the concentration of this substance in the food and in representative samples of the faeces of each animal is determined, the ratio between the concentrations gives an estimate of diet digestibility.

$$\text{i.e. Digestibility} = \frac{\text{indicator in faeces (g/kg DM)} - \text{indicator in food (g/kg DM)} \times 100}{\text{indicator in faeces (g/kg DM)}}$$

The inert indicator used may be a natural constituent of the food (e.g. lignin) or may be added to it. The substance most commonly added is chromic oxide, (Cr_2O_3) which is relatively cheap, inert, non toxic and has given recoveries close to 100% in many experiments with ruminants (Stevenson and De Langen 1960; Curran, Leaver and Weston 1967).

The determination of faecal output and hence digestibility using chromic oxide was originally used (1918) in compound feeds in indoor experiments (described by Edin, Kihlen and Nordfedt 1974).

Chromic oxide has since been extensively used in trials involving housed ruminants (Crampton and Lloyd 1951; Davies, Byers and Luber 1958; Luttingh 1961; Clanton 1962; Leaver, Campling and Holmes 1969; Wilkinson and Prescott 1970).

Chromic oxide has also been used in experiments where an assessment of herbage intake is required. If the faecal dry matter output is known together with a separately determined estimate of the digestibility of the grazed herbage, the intake can be derived from the following equation.

$$\text{Herbage intake, g DM/day} = \frac{\text{Faecal output, g DM/day}}{\text{\% Indigestibility of DM}}$$

The above equation may also be employed to measure the DM intake of housed ruminants in group feeding situations.

Numerous studies have been undertaken where chromic oxide has been used to determine the faecal output of grazing animals, (Cowlishaw and Alder 1963 for steers; Holmes, Jones, Drake-Brockman and White 1965; Holmes, Jones and Adeline 1966; Holmes and Curran 1967; Marsh, Campling and Holmes 1971 and Holmes, Campling and Joshi 1972 for dairy cows; Lambourne 1957; Lambourne and Reardon 1962 and Langlands 1972 for sheep and Coup and Lancaster 1952; Christian and Coup 1954 and Stevenson 1962 for both cattle and sheep). The faecal output is derived as follows;

$$\text{Faecal DM output} = \frac{\text{Weight of chromic oxide given (g)}}{\text{Concentration of chromic oxide in faeces (g/kg DM)}}$$

The digestibility of the herbage consumed has been evaluated by a variety of methods including the giving of cut herbage to wether sheep in metabolism cages and relating the nitrogen content of the faeces of the grazing animals to the organic matter digestibility using regression equations derived from results with the housed sheep. (Langlands and Corbett 1964; Jones et al. 1965; Holmes and Curran 1967; Holmes et al. 1972). Other workers (Langlands 1972) relied on in vitro digestibility estimates on samples of food collected from sheep, each fitted with an oesophogeal fistula. Plant chromogens have also been employed as indicators of herbage digestibility (Hardison and Reid 1953; Raymond, Kemp, Kemp and Harris 1954).

The individual variation in intake of a dietary component can be determined for group-fed animals using chromic oxide incorporated in that component of the diet to be examined. The faeces must then be collected in total. Foot and Russel (1973) used non-pregnant ewes given hay plus oat pellets containing 15·7 g chromic oxide/kg DM, Foot, Russel, Maxwell and Morris (1973) gave pregnant ewes in group hay plus concentrates containing 0·93 g chromic oxide/kg. The individual intakes of the dietary component containing chromic oxide are estimated from the individual faecal chromic oxide output using the following equation.

$$\text{Individual intake of chromic oxide containing food} = \frac{\text{Mean daily faecal DM output (g)} \times \text{concentration of chromic oxide in Faeces (g/kg DM)}}{\text{Concentration of chromic oxide in food (g/kg DM)}}$$

When the recovery of chromic oxide is not fully quantitative the individual intakes are usually derived by apportioning the total amount of food consumed by the group according to the total chromic oxide recovered.

Methods of chromic oxide administration

The determination of faecal output using chromic oxide, is most commonly achieved by giving weighed quantities once or twice daily. Several methods of administration have been reported, these include the mixing of chromic oxide in a uniform manner in a compound diet or concentrate (Edin et al. 1944; Crompton and Lloyd 1951; Kameoka, Takahashi and Morimoto 1956; Corbett, Greenhalgh, Gwynn and Walker 1958; Holmes and Curran 1967; Leaver et al. 1969; Marsh et al. 1971; Holmes et al. 1972), at a concentration such as to provide about 2 g Cr_2O_3/day for sheep and between 15 - 20 g/day for cattle. Other workers (Corbett, Greenhalgh and Mcdonald 1958; Cowlishaw and Alder 1963; Deinum, Immink and Deijs 1962; Troelsen 1965; Macrae and Armstrong 1969; Wilkinson and Prescott 1970; Longsdale, Poutiainen and Taylor 1971) have introduced chromic oxide into the ruminant animal using paper impregnated with chromic oxide, the paper usually containing about 333 g chromic oxide/kg. A further method of administration is that employed by Raymond and Minson (1955) where chromic oxide was given as a drench in a bentonite suspension. The most widely used method of administration however, appears to be in the form of purchased gelatin capsules containing a suspension of chromic oxide in maize oil (Smith and Reid 1955; Jones et al. 1965; Holmes et al. 1966; Hodgson and Wilkinson 1967; Longsdale et al. 1971 in trials using grazing dairy cows; and Langlands et al. 1963 and Curran et al. 1967 in trials with grazing sheep).

With all methods of chromic oxide administration the dosing period should preferebly commence at least 7 days before the initiation of the experiment to ensure proper distribution throughout the contents of the alimentary tract. Equilibrium between chromic oxide input and faecal output is reached between day 5 and 7 of dosing (Crampton and Lloyd 1951; Corbett et al. 1960).

Long term errors associated with chromic oxide recovery

The early literature concerning the recovery of chromic oxide in the faeces has been reviewed by Moore (1959) but the most accurate method of chromic oxide introduction is still not clear. The precise meaning of the term 'percentage recovery,' was clarified by Curran et al. (1967) who defined the weight of marker recovered in total faecal collections expressed as a percentage of the weight of the marker given as the 'absolute' chromic oxide recovery, as opposed to the 'relative' chromic oxide recovery, which is used to express the concentration of the marker in a given sample of faeces as a percentage of the mean daily concentration in the faeces. This latter term does not necessarily imply a total recovery of the marker in the faeces. Assuming that chromic oxide is completely indigestible the 'absolute' recovery in the faeces should be 100% for a valid interpretation of the data to be made. Alternatively, if the 'absolute' recovery is less than 100% a correction factor can be applied to the data to allow for this under the particular experimental conditions (Stevenson 1962). Many factors contribute to the overall error in the 'absolute' faecal recovery of chromic oxide and hence, biased results. These may include (a) an inaccurate estimate of the amount of chromic oxide administered, (b) regurgitation of gelatin capsules or paper, (c) absorption of soluble chromates (d) retention of chromic oxide in the alimentary tract, (e) incomplete collection of faeces, (f) losses in the grinding of faecal samples, as chromic oxide is more dense than faecal DM and separation may occur (Stevenson 1962) and (g) analytical errors.

In an experiment involving dairy cows where chromic oxide was administered as chromic oxide impregnated paper, Deinum, Immink and Deijs (1962), reported traces of chromic oxide in the liver, lymph glands, kidneys and urine which they suggested were due to absorption of that given orally. Curran et al. (1967), postulated that when chromic oxide is administered in a highly concentrated form as in capsules or in the cubed compound feed of Crampton and Lloyd (1951), it is partially retained in the digestive tract and a 100% 'absolute' recovery is not achieved over the experimental periods.

Comparisons of the 'absolute' recoveries of chromic oxide by various authors using the different techniques of administration illustrate a wide range of accuracy. Johnson, Dinusson and Bolin (1964), reported that only 84·8% of the marker was recovered when used as a feed constituent in powder form but 91·3% was recovered when used in the form of impregnated paper in the pelleted ration. Wilkinson and Prescott (1970) in a trial using group-fed Friesian steers and chromic oxide impregnated paper achieved a low absolute recovery of 85 - 91% but a loss of material from the faecal collection bags was observed at the lower range. Troelsen (1965) reported similar low recoveries of about 85 - 90% using shredded chromic oxide paper given to ruminants consuming long roughage diets. Crampton and Lloyd (1951), reported that the absolute recovery of chromic oxide given as 10 g/kg of a major part of the pelleted ration to be 98 — 99% whereas that of chromic oxide given as 280 g/kg of a small part of a pelleted ration was only 85 - 87%. Curran et al. (1967), in a trial with three housed, pregnant cows given differing proportions of a hay/concentrate diet (with 9·0 g/kg chromic oxide) providing a nutrient intake of 1·33 x maintenance, achieved an 'absolute' recovery of 97·3 - 103·1% (mean, 100·9%) when total faecal collections were employed and 95·4 - 106·4 % (mean, 99·4%) using rectal grab samples. Corbett et al. (1958), gave cows a cubed concentrate containing 70·8 g Cr_2O_3/kg to provide daily intakes of 14·2 - 56·6 g; a mean absolute recovery of 97·2% was recorded for a 5-day period. Murdock, Hodgson, Miller and Kimura (1957), obtained comparable recoveries of 94·0, 90·3 and 98·4% in trials giving gelatin capsules containing chromic oxide to yearling heifers. In a parallel trial to that using 90 g/kg chromic oxide incorporated in the concentrate, Curran et al. (1967) gave 8 housed, pregnant cows a similar diet, but introduced chromic oxide in the form of two gelatin capsules, each containing 9·81 $\pm$ 0·02 g Cr_2O_3 at 07.15 and 15.15 hr. They obtained low recoveries of chromic oxide of between 82·8 - 93·5% (mean 89·8%) using a total faecal collection and 77·2 - 109·7% (mean 90·0%) with rectal grab samples. In a further trial with 8 grazing sheep dosed once daily with two capsules each containing 0·98 ± 0·04 g Cr_2O_3 at 15.30 hr the 'absolute' recovery of chromic oxide using total faecal collections was 88·8% (range 83·2 - 93·5%). Similar animals individually given 227 g for a cubed concentrate containing 4 g Cr_2O_3/kg in one daily feed at 15.30 hr produced a high mean absolute recovery of 98·5% (range 90·8 - 113·9%). Coup (1950) reported variable results from the use of gelatin capsules; in two trials recoveries were low (87·4 and 88·8%) while in other trials higher recoveries of 97·4 to 101·2% were recorded. These latter results are in agreement with the work using capsules quoted by Smith and Reid (1955) and Cowlishaw and Alder (1963) who obtained adequate recoveries using gelatin capsules.

Thus, there appears to be considerable disagreement concerning the efficacies of the different modes of Cr_2O_3 administration. Curran et al. (1967), concluded that in view of the high recoveries (not significantly different from 100%) achieved when chromic oxide was given in the feed and the saving in cost made using this technique (if concentrates are a normal part of the diet) compared to the use of purchased gelatin capsules; it is preferable to use chromic oxide in the feed whenever possible.

Short term errors

(a) Periodicity of chromic oxide excretion

Undoubtedly the major advantage of using chromic oxide to estimate faecal output is that it removes the laborious necessity of undertaking total faecal collections. A resultant problem associated with the use of chromic oxide as an inert, faecal indicator has been the procurement of faecal samples truly representative of the whole excreta. In earlier indoor experiments (Edin et al. 1944), the tracer was mixed with the whole feed and so was distributed fairly uniformly in the faeces. As a result, sampling of the faeces presented no great problem. However, it was not at first realised that under grazing conditions the tracer is not uniformly mixed with the feed and so is excreted irregularly in the faeces. This makes the careful sampling of the faeces of paramount importance.

The existence of a diurnal excretion pattern of chromic oxide in the faeces has been recognised by a number of researchers (Kane, Jacobsen and Moore 1952; Kane, Jacobsen, Ely and Moore 1953; Smith and Reid 1955; Hardison, Engel, Linkous, Sweeney and Graf 1956; Bloom, Jackobsen, Allen, McGillard and Homeyer 1957; Putnam, Loosli and Warner 1958 using dairy cows; Hardison and Reid 1953; Balch et al. 1957; Wilkinson and Prescott 1970 using steers).

Kane et al. (1952), demonstrated a diurnal pattern of excretion of chromic oxide in the faeces and suggested from this, it should be possible to predict sampling times at which faeces containing the true average concentration of chromic oxide would be obtained. Hardison and Reid (1953) as a result of trials involving steers at grass, proposed that the bulking together of equal weights of faeces sampled at 06.00 and 16.00 hr during 7 or more days would provide samples of which the chromic oxide concentration would allow an accurate estimate of the total faecal output to be derived. The results of subsequent experiments conducted by Brannon, Reid and Miller (1954) with steers supported this. Lancaster, Coup and Percival (1953) and Smith and Reid (1955) obtained accurate estimates of faecal output by grazing cows using essentially the same sampling procedure as that of Hardison and Reid (1953).

Kane et al. (1952) believed that the reason for this diurnal pattern in chromic oxide excretion corresponded to changes in metabolism, blood pressure and blood metabolic concentration which undergo cyclical changes reaching their lowest level at night when the lowest concentrations of chromic oxide in the faeces were recorded.

Bloom et al. (1957) and Edin et al. (1944), supported the view that the 'inherent periodicity in the excretion pattern of chromic oxide,' was governed by some intrinsic physiological mechanism rather than the effect of time, frequency or method of dosing in relation to the pattern and level of feed intake. Bloom et al. (1957) in a digestibility trial using housed dairy cows reported that the diurnal excretion pattern was largely independent of the wide variation in the amount and physical nature of the diets provided, agreeing with the studies of Kane et al. (1952).

Clearly the use of rigid faecal sampling times irrespective of the experimental conditions as advocated by Hardison and Reid (1953) would be a valid assumption within a livestock class if the diurnal excretion pattern of chromic oxide was governed purely by physiological mechanisms similar to those proposed by Kane et al. (1952). Further work, however, has shown this not to be the case; Raymond and Minson (1955) indicated that the excretion pattern of chromic oxide and, in particular, the times of maximum and minimum concentrations in the faeces, depend among other factors on the times and method of dosing in relation to the amount and pattern of feed intake. Brisson (1960) pointed out the need to define possible sources of variation in the chromic oxide excretion pattern for each set of experimental conditions. Also, it has been clearly shown by Pigden and Brisson (1956) that the range of the diurnal variation of chromic oxide concentration in the faeces is reduced by frequent dosing during a 24-hr period, but this is generally impractical in grazing experiments. This work contrasts with the results of Bloom et al. (1957) who, using housed dairy cattle, did not find this to be the case. An appreciable range in the diurnal variation pattern was observed even though the chromic oxide given was four times daily in a concentrate mixture.

Further evidence discounting the theory that the diurnal excretion pattern is solely governed by inherent physiological mechanisms has been provided by Putnam et al. (1958), in studies on the excretion of chromic oxide by dairy cows. They reported that there was considerable variation in relative chromic oxide concentration at any sampling time. It was concluded that the time of chromic oxide administration was of primary importance in respect to the time-concentration relationship of faecal chromic oxide concentration and that so called physiological, diurnal effects were of little importance.

Wilkinson and Prescott (1970) in a trial using individually housed steers gave a diet of rolled barley twice daily with silage ad libitum. Chromic oxide was administered in the form of shredded paper twice/day before each feed of barley. The sampling of faeces occurred at each natural defecation for three, 24-hour periods. They observed a significant and consistent diurnal variation in faecal chromic oxide excretion with the lowest concentration occurring during the night. This pattern of diurnal variation is similar to that obtained by other workers (Kane et al. 1952; Hardison et al. 1956; Balch et al. 1957; Putnam et al. 1958). Wilkinson and Prescott (1970) reported that concurrent grab samples taken at 09.15 and 17.00 hr over four days gave estimates of chromic oxide which were about 16% higher than the mean concentration for the three 24-hour sampling periods. They also indicated that the periodicity of faecal excretion of chromic oxide may be related to the pattern of feed intake, rate of digestion and the rate of passage of undigested residues through the alimentary tract as well as the physiological mechanisms proposed by Kane et al. (1952). It was stated that the higher the intake of feed, the more rapidly the maximum concentration of chromic oxide occurs in the faeces, probably because of the higher rate of passage of feed residues down the intestine.

Kameoka et al. (1956) measured the rate of disappearance of chromic oxide from the rumen. The concentration decreased during the first 3 hours after administration to about 70% of the initial concentration and then maintained this level until the next meal. They concluded that chromic oxide was removed more quickly from the rumen than the usual constituents of the feed.

Troelson (1965), in a trial involving housed sheep receiving 2 g chromic oxide/day in the form of a paper pellet at 09.00 hr for a 10-day period reported that when a long hay diet was given and faeces sampled hourly there was little diurnal variation in the chromic oxide content of the faeces, but when long hay was compared with pelleted hay a difference in the degree of diurnal variation was noticed between the different physical forms.

A reduction in the variation in the chromic oxide content of faeces samples has been noted by Corbett et al. (1960) when it was administered on shredded paper, by Hardison et al. (1956) when it was administered twice daily, and by Balch et al. (1957) when it was administered before a meal.

In summary, the short term error component affecting the accuracy of the chromic oxide indicator technique due to the diurnal variation in the faecal excretion pattern can be attributed to a variety of factors including daily dosing pattern, method of dosing in relation to the pattern and level of feed intake, physical nature of the diet as well the hypothesis postulated by Kane et al. (1952) and Bloom et al. (1957) that the excretion of chromic oxide is regulated by a physiological mechanism removing surplus and unusable substances from the body; this mechanism being independent of feed intake pattern and dosing interval. Therefore it is necessary to define the diurnal variation pattern for each set of experimental conditions with particular reference to diet, before the chromic oxide concentration of grab samples taken at various times can be corrected to take account of diurnal variation. Alternatively it is possible to select sampling times by reference to diurnal excretion curves at which the chromic oxide content is closest to the mean.

(b) Inter-day variation in chromic oxide excretion

A further component contributing a possible short term error in the chromic oxide faecal indicator technique is the day-to-day variation in the chromic oxide content of faeces samples (Kameoka et al. 1956; Corbett et al. 1960; Wilkinson and Prescott 1970). A measure of the combined short term errors due to both the diurnal excretion pattern and day-to-day-variation in chromic oxide content of the faeces can be derived from the difference between the 'absolute' recovery and the 'relative,' recoveries (Wilkinson and Prescott, 1970). These workers obtained a relative recovery figure close to 100% in a trial with 8 Friesian steers given silage ad libitum and two levels of barley (1·8 or 3·6 kg/day). Chromic oxide was administered in two feeds at 09.00 and 16.30 hr in the form of shredded paper before each meal. Faecal grab samples were obtained at 09.15 and 17.00 hr each day for 4 consecutive days in three separate 4-day faecal sample periods. The mean coefficients of day-to-day variation for the two barley groups were 9.9% and 6·2%. These coefficients are considerably higher than the 3% coefficient of variation obtained by Corbett et al. (1960) for day-to-day variation using a 7-day grab sampling period. A poor correlation between the chromic oxide content of the bulked 4-day samples and the mean content of 4 separate daily samples was also obtained by Wilkinson and Prescott (1970). They concluded that the length of sampling period may be likely to influence the degree of error associated with the mean chromic oxide content of bulked grab samples and it is therefore preferable to use as long a sampling period as possible in order to minimise the interday variation in chromic oxide excretion and recovery. Kameoka et al. (1956) reported that this variation was a normal occurrence, amounting to about 10%. They postulated that it might be due to the following reasons; (a) Variation in the faecal DM output usually in the region of between 10 - 15%. (b) Possible accumulation of chromic oxide in some parts of the ruminant digestive tract such as the omasum and abomasum by unknown means and its irregular excretion leading to abnormal concentrations from day-to-day.

Summary

In conclusion the use of chromic oxide in ruminant feeding trials is subject to several sources of error of both a short term (diurnal variation and interday variation in faecal output with a concomitant variation in faecal chromic oxide concentration) and a long term nature, (an 'absolute' recovery of chromic oxide considerably less than 100%). However, by careful attention to the selection of the most accurate method of giving chromic oxide (usually its inclusion at an appropriate level in a major portion of a concentrate in the diet) and the use of grab sampling times which make an allowance for the periodicity of chromic oxide excretion and the adoption of a sampling period over as many days as is conveniently possible, it should be possible to reduce the magnitude of the errors associated with the chromic oxide faecal indicator technique to an amount equal to that achieved using total faecal collections.

I(ii) The distribution of chromic oxide within and between feedblocks

The accurate estimation of individual intakes of feedblock material using chromic oxide depends on the uniform distribution within and between feedblocks. The chromic oxide containing feedblocks were made by the normal commercial manufacturing processes in batch sizes of usually 1 to 3 tonnes. In order to measure the distribution of chromic oxide within individual feedblocks for any batch, several blocks were randomly chosen and core samples removed from six random sites using a brace and bit. This procedure also gave an indication of between feedblock chromic oxide variation. A more detailed examination of chromic oxide variation between feedblocks was undertaken for the W290(74)and W291(74) products. This involved the separate sampling in three places of a larger number of feedblocks in their respective batches and bulking the material from each block. A single chromic oxide determination was then undertaken for each block. The mean chromic oxide inclusions in several different feedblocks of the same type, together with the coefficient of variation for chromic oxide inclusion within and between blocks is given in Table 2.

The distribution of chromic oxide within and between feedblocks appeared to be quite uniform and no significant difference in mean inclusion rate for blocks of the same type were measured. Even the W290 and W291(74) products manufactured by the chemical setting reaction contained relatively uniform inclusions of chromic oxide. This process has the disadvantage of critically short mixing time for the ingredients before setting commenced and occasionally aggregates of calcium oxide and/or hydroxide were observed, indicative of inefficient mixing. However, the data in Table 2 reveal no detrimental effect on the dispersal of chromic oxide.

I(iii) The effect of length of sampling period, no. of animals/group and the quantity of feedblock and roughage consumed on the accuracy of the following estimations

(a) Individual feedblock intake using chromic oxide.

(b) Dietary digestibility using both total faecal collections and chromic oxide.

(c) Hay intake as computed by apportioning faeces according to the indigestibility of the separate dietary components.

Amongst the many potential applications of the use of chromic oxide in diets is the prediction of individual feed intake in group situations if the diet or a dietary component contains chromic oxide e.g. Beames and Morris (1965) for feedblocks and Foot and Russel (1973)

Table 2. Variation in chromic oxide concentration within and between Feedblocks

Mean (±SE) chromic oxide concentration (g/kg DM)

Variation within feedblocks

	Individual feedblocks				
	A	B	C	D	E
RHE	** 5.10±0.08	5.22±0.09	5.03±0.11	5.09±0.08	5.06±0.06
CV%*	3.8	4.3	5.1	3.6	2.9
RS	4.40±0.11	4.33±0.09	4.52±0.11	4.32±0.11	4.36±0.09
CV%	6.1	4.9	6.2	6.4	5.3
W290(74)	2.50±0.04	2.35±0.05	2.43±0.06	2.46±0.03	2.33±0.06
CV%	3.5	4.7	5.8	3.2	6.1
W291(74)	2.45±0.07	2.34±0.08	2.66±0.08	2.41±0.09	2.37±0.07
CV%	6.7	8.1	7.2	9.3	6.9

Variation between feedblocks

	No. examined	Mean chromic oxide g/kg DM	CV%
W290(74)	32	2.38±0.02	4.9
W291(74)	32	2.41±0.04	8.9

* Coefficient of variation % (CV) = $\frac{\text{standard deviation of mean}}{\text{Mean}} \times 100$

** Each a mean of six samples.

for concentrate pellets. The individual intake of the feeding stuff containing chromic oxide is derived by reference to the amount of chromic oxide recovered in the faeces. The equation used is given on page 40.

For the purpose of this thesis it was essential to have a technique for estimating the individual intake of feedblocks and other dietary supplements with reasonable accuracy. Chromic oxide was chosen as the most applicable marker and as the use of rectal grab samples is rather an imprecise means of assessing supplement intake, wherever possible (logistically) total faecal collections were made. Nevertheless in many of the circumstances prevailing in the experiments undertaken, it was impractical for total faecal collections to be accomplished. For instance, when large numbers of animals were involved, handling facilities were absent, and when cattle were used as the experimental animals, it was rarely possible to base individual supplement intakes on anything other than the chromic oxide content of the rectal grab samples.

As it would have been somewhat artificial to carry out the proposed individual variation studies with male animals, a faecal bag of the nylon mesh type was used to totally collect faeces from ewes. The design of the bags was such that when the ewes adopted the position for urination, the urine voided generally passed in front of the bag. When the bag was about full of faeces urine percolated rapidly through the contents.

Before any individual estimates of supplement intake could be derived in the group situation, the absolute recovery of chromic oxide using nylon mesh bags had to be measured in a controlled situation where chromic oxide intakes were accurately recorded. The effect of the length of sampling period on the reliability of this procedure was also examined when the recoveries from various numbers of animals were combined together. Thus, one of the main objectives of these initial studies was the establishment or otherwise of chromic oxide as an accurate means of predicting individual intakes using nylon mesh faecal bags.

Secondly as many of the proposed experiments entailed the measurement of diet digestibility, a further objective of these experiments was the comparison in terms of accuracy of digestibility coefficients derived from total faecal collections and the chromic oxide indicator technique using rectal grab samples. The latter method would be especially used for the computation of digestibility data for cattle. Again the effect of length of sampling period on the accuracy of these measures was examined for various sized groups of sheep.

In many circumstances a knowledge of individual roughage intakes and their variation for combined roughage-supplement diets is necessary for a full understanding of nutrient intake and resulting animal performance. The accurate estimation of the intake of the roughage dietary component in these situations is likely to be difficult because of associative effects between the two (or more) dietary components. One of the principal claims made for feedblocks is that they improve the digestibility of poor quality roughages. Therefore when, for instance, a feedblock forms only a small part of a total diet (i.e. a true supplement), based mainly on poor quality roughage, the estimation of roughage intake by apportioning faeces according to the indigestibility (100 - digestibility %) of the different dietary components may be invalidated by changes in digestibility if there are associative effects. Usually this takes the form of increased roughage digestibility. Also, as will be described later, it is rarely possible to measure meaningful digestibility coefficients of supplement feedblocks.

When, however, the proportion of feedblocks or concentrate in the diet increases to a level where it is substituting rather than supplementing for the roughage, an individual assessment of roughage intake derived from faecal apportionment is more likely to be valid.

This is particularly the case if the roughage given is of good or moderate quality (greater than 50 g CP/kg). A third objective of these initial experiments was to examine the accuracy of estimating roughage intake by faecal apportionment according to indigestibility coefficients for diets composed of moderate quality hay and feedblock material. Again the effect of length of sampling period for different numbers of animals on the accuracy of this estimation was examined.

Experimental

Thirty two, non-pregnant, non-lactating Greyface (Border Leicester ram x Scottish Blackface ewe) ewes weighing 49 to 71 kg were housed in individual pens (2 m x 1 m) with sawdust bedding. All ewes were dosed with anthelmintics prior to housing.

Three experiments were conducted. In Experiment 1.1 the ewes were given a diet consisting of 505 g DM of feedblock material (W290(74)) of composition Table 1, in a meal form plus 526 g DM of chopped hay (82 g CP, 274 g CF, 17 g EE and 61 g ash/kg). The block meal also contained 2·185 g chromic oxide/kg DM. The DM digestibility (65·7 ± 1·3%) of the feedblock material was measured in a digestibility by difference trial with 4 wethers given a basal ration of 0·9 kg DM high quality dried grass pellets. The DM digestibility of the hay was 59·4 ± 2·3%.

Following an introductory period of 7 days to the diet, total faecal collections from 24 of the ewes were made using harnesses and nylon mesh faecal bags. The daily fresh faecal output from each sheep was weighed, thoroughly mixed and a 10% subsample retained for each of the following sampling schedules. The output over days 1 to 9 formed a 9-day composite sample; the faecal output over days 1 to 3, 4 to 6 and 7 to 9 formed three separate 3-day composite samples. The faecal output over days 1 to 6 and 4 to 9 was derived by combining the data from the 3-day collections (1 to 3 plus 4 to 6) and (4 to 6 plus 7 to 9) respectively. After determining DM for each composite sample and milling chromic oxide was determined. Therefore the absolute recovery of chromic oxide was computed with 24 sheep for either 9 days of continuous sampling, 2 separate 6-day continuous sampling periods or 3 separate 3-day continuous sampling periods. Dry matter digestibility and hay intakes estimated by apportioning faeces according to the indigestibility of the feedblock and hay, were calculated in a similar way for the various sampling schedules.

The remaining ewes were grab sampled per rectum twice daily at 08.00 and 16.00 hr and the grab samples combined to form the various different composite samples as for the total collection ewes. The DM digestibility of the diet was then estimated using the chromic oxide faecal indicator technique for the various sampling schedules.

In Expt 1.2, the 32 ewes were allocated to 8 groups of 4 sheep on the basis of live weight. Four groups (16 ewes) were given 384 g DM of the chopped hay, plus either 82, 164, 328 or 656 g of feedblock meal DM. One of the other 4 groups received 769 g DM chopped hay alone, while the remaining 3 groups were given 328, 493 or 657 g DM of feedblock meal with no roughage. The last 3 treatments produced severe scouring on the sheep and the 493 and 657 g levels were discontinued. Following 7 days of introduction to the diets total faecal collections of 7 days duration were carried out for all ewes. The absolute recoveries of chromic oxide, DM digestibilities and estimated hay intakes were calculated as in experiment 1.1 except in this case the length of sampling period was constant for all treatments at 7 days.

In Expt 1.3 the 32 ewes were again allocated to 8 groups of 4 sheep. Four groups were given 769 g DM of chopped hay plus either 82, 164, 328 or 656 g DM of feedblock material. The remaining 4 groups received the respective feedblock meal allocations but with chopped hay given ad libitum. In this latter case the hay feeders were replenished up to 4 or 5 times daily when necessary. Faecal collection and sampling procedures were as for experiment 1.2.

Subsequently the elimination of chromic oxide from the faeces of sheep previously given chromic oxide containing feedblock meal was monitored for the groups given 82 g DM feedblock meal plus 384 g DM hay (Expt 1.2) and 656 g DM of feedblock plus hay ad libitum (Expt 1.3). A constant daily 400 g subsample of fresh faeces was retained from each sheep for DM and chromic oxide determination. The total daily chromic oxide output was then computed over a 10-day period after the cessation of chromic oxide feeding.

In each of the experiments the allocations of feedblock or hay when restricted were given in two daily feeds at 08.00 and 16.00 hr. Food residues (only on the 565 g allocation of feedblock) were retained and analysed for DM content and adjustment made to the total chromic oxide intake when appropriate.

The individual water consumption of the ewes was measured in the sampling periods of all three experiments.

Results

Expt 1.1

The absolute chromic oxide recoveries, DM digestibilities and estimated hay intakes are given in Table 3. The overall mean water intake was $3 \cdot 64 \pm 0 \cdot 14$ litres/day.

The absolute mean recovery of chromic oxide in the faeces of the 24 sheep was always within the range of 98·6 to 101·1% of that given which establishes the accuracy of the input/output data and the analytical method. The mean CV for the three 3-day collection periods for the 24 sheep was 7·1% and this was reduced to 4·4% for the two 6-day collection periods and to 4·3% for the 9-day collection.

For the 24 sheep the total DM digestibility was always within the range 64·0 to 64·6 (mean 64·4) irrespective of the length of period of

Table 3. Expt 1.1. The mean absolute recovery of chromic oxide, DM digestibility and the estimated daily intake of hay

Total faecal collection (Mean, 24 sheep)							Rectal grab samples (Mean 8 sheep)	
Sampling period days	Absolute chromic oxide recovery		DM digestibility		Estimated hay intake		DM Digestibility	
	%	CV%*	%	CV%	g	CV%	%	CV%
3-day collections								
(a) 1 - 3	100.2	6.0	64.5	4.3	489	11.6	63.6	4.3
(b) 4 - 6	98.6	7.9	64.4	3.4	496	10.1	64.4	2.4
(c) 7 - 9	100.1	7.4	64.0	3.8	501	9.6	64.5	1.8
6-day collections								
(a) 1 - 6	99.5	4.1	64.5	3.3	490	9.7	64.1	3.5
(b) 4 - 9	99.5	4.7	64.2	3.1	499	8.6	64.6	2.0
9-day collections								
(a) 1 - 9	101.1	4.3	64.6	3.1	485	10.6	63.8	4.7

* Coefficient of variation %.

faecal collection and the mean CV of 3·8% for the 3-day collections was reduced to 3·2 and 3·1% for the 6 and 9-day collections respectively. The overall mean DM digestibility estimated from the faecal grab samples from 8 sheep was 64·2% and the CV was (surprisingly) rather less (3·1 compared with 3·5%) than that for the complete collection from 24 sheep but was rather more variable for the various periods.

The various sampling procedures always resulted in an underestimate (4·8 to 7·8%) of the amount of hay given. There was slightly less variation for the two 6-day collection periods.

Expts 1.2 and 1.3

Table 4 presents the combined results for Expts 1.2 and 1.3. The results for the sheep given 328 g feedblock/day alone are not presented as the faeces were too soft and wet to be collected properly in the nylon mesh bags and the determined recovery was only 83·5% of that given.

The overall mean recovery of chromic oxide was 97·8% of the intake. The individual mean values were generally between about 96 and 102%. Lower or higher recoveries were not associated with any trend in either hay or feedblock intake. The CV for each group of 4 sheep was generally about 2·0 to 7·0% of the mean but three groups had higher values of between about 10 and 13%. In general the CV values obtained over a 7-day period were comparable to those obtained for 6 or 9-day periods in Expt 1.1. The lowest CV values recorded were those for the highest (656g) intake of feedblock.

The DM digestibilities of the various feedblock-hay combinations were in close agreement with values calculated from the DM indigestibility coefficients of the respective dietary components. This was reflected in the estimated hay intakes which were generally in agreement with the weighed inputs with no consistent under or overestimate emerging. The CV for estimated hay intakes were always larger for the

Table 4. Expts 1.2 and 1.3. Mean chromic oxide absolute recoveries, DM digestibilities, estimated hay intakes and water consumption for diets.

(Mean of 4 sheep)

Hay g/day	Feedblock g/day	384		769		Ad libitum*	
Chromic oxide recovery % and (CV%)	82	99.9	(10.2)	106.8	(6.4)	97.5	(7.0)
	164	91.6	(5.0)	98.8	(13.4)	96.5	(4.2)
	328	99.1	(2.0)	98.5	(3.7)	91.3	(13.4)
	656	95.8	(4.2)	96.8	(3.3)	101.9	(3.1)
DM digestibility % and (CV%)	82	63.2	(8.2)	60.2	(4.0)	60.3	(3.6)
	164	66.5	(4.5)	60.9	(4.6)	60.2	(5.3)
	328	63.0	(6.7)	62.5	(1.0)	61.4	(10.1)
	656	63.4	(4.7)	62.6	(1.3)	64.6	(2.8)
Estimated hay intake g/day and (CV%)	82	356	(14.1)	803	(9.5)	1615	(4.8)
	164	370	(21.8)	770	(7.9)	1463	(16.7)
	328	383	(18.5)	791	(8.7)	1369	(26.3)
	656	419	(12.3)	796	(7.2)	1457	(25.4)
Water consumption litres/day	**82	1.45		2.11		4.07	
	164	1.53		2.52		3.38	
	328	2.67		2.84		4.69	
	656	4.11		5.40		6.74	

* Ad libitum consumption was 1600±179, 1535±123, 1348±188 and 1453±109 g DM/day for block intakes of 82, 164, 328 and 656 g/day respectively.

** S. Error of difference between 2 means, 0.42 litres/day.

384 g allocation of hay than when 769 g hay was given. When hay was offered ad libitum an extra source of variation apart from that inherent in the estimation technique was introduced, namely the between sheep differences such as live weight which influence voluntary hay intake and the CV increased from about 5 to about 25% as the feedblock intake increased from 82 to 656 g DM/day.

Table 5 indicates the manner in which chromic oxide diminished in the faeces following the withdrawal of chromic oxide-containing feedblocks from the 2 groups of 4 sheep.

Table 5. Expts 1.2 and 1.3. Progressive % reduction in the chromic oxide content of the faeces (mean 4 sheep/group)

Block intake g/day		82	656
Chromic oxide intake (mg/day)		211	1680
Previous 7 days		100	100
Days after withdrawal	1	100	57
	2	56	28
	3	35	14
	4	18	9
	5	9	6
	6	4	2

The elimination of both high and low intakes of chromic oxide from an 8 fold difference in block intake was substantially complete after 6 days and was reduced to almost one half after 1 or 2 days.

The water consumption of the ewes increased proportionally with the total DM intake. There was also a tendency for water consumption to increase in response to quantity of feedblock given independent of total DM intake and particularly when feedblock intake was 656 g/day. For example, sheep given 769 g hay alone consumed 2·23 l/day while sheep given 712 g (384 g hay + 328 g feedblock) consumed 2·67 l/day.

Discussion

The results of all three experiments described here confirmed the effectiveness of chromic oxide and the faecal collection apparatus (nylon mesh bags) as a useful and accurate method of assessing individual intake of chromic oxide containing foodstuffs. Neither length of sampling period nor number of sheep per group appeared to have a profound effect on the accuracy of the measure.

It would seem that if necessary even 3 days of continuous faecal collection would give a quantitative recovery of the chromic oxide consumed with a low CV (6 - 8%) for a group size of 24 animals. When the collection interval was increased to 6 continuous days the CV was reduced to between 4 - 5%. A further increase to 9 continuous days made virtually no improvement on accuracy. (CV = 4·3%).

When the group size was reduced to 4 sheep and a collection period of 7 continuous days adopted the CV for feedblock intake was on average 6·3% for 12 groups of 4 sheep given varying amounts (82 – 656 g DM/head) of chromic oxide-containing feedblock. Therefore under the circumstances of Expts 1.1, 1.2 and 1.3 the amount of variation attributable to the experimental error in estimating individual feedblock intake was acceptably low.

As the computation technique for individual feedblock intake is partly a function of total faecal DM output, the accuracy of measuring diet digestibility by total quantitative collection was also confirmed.

It was also shown (Expt 1.1) that the chromic oxide inert indicator technique was a very accurate means of estimating diet digestibility under the current circumstances irrespective of whether rectal grab samples were obtained twice daily for either 3, 6 or 9 days.

The technique of estimating individual roughage intake by faecal apportionment according to the indigestibility of the 2 dietary components allowed a reasonably accurate prediction to be made under the experimental circumstances. The mean estimated intakes (4 sheep) agreed closely with the weighed outputs when either a low, medium or ad libitum allocation of roughage was given. Any discrepancies occurring were probably due to spillage of hay rather than associative effects between the dietary components. The CV for estimated hay intake were however higher on the lower (384 g DM/head) allocation than when (769 g DM/head) was given. Any spillage which did occur would form a larger proportion of the mean at the lower level of allocation. In most of the experiments described in this thesis where faecal apportionment was used to estimate individual intake ad libitum roughage was given.

When a low quality roughage (straw or poor quality hay CP < 50 - 60 g/kg DM) is given to sheep, in addition to either feedblocks or concentrates containing supplementary nitrogen, an associative interaction between the dietary components resulting in increased roughage digestibility cannot be disregarded. This would make the prediction of individual roughage intakes by faecal apportionment less accurate unless account of these likely associative effects is taken.

The data on disappearance of chromic oxide from the faeces of sheep as occurred when the giving of chromic oxide (feedblock) ceased abruptly, suggests that a minimum period of at least 4 - 5 days must elapse before individual intakes are reassessed after changing experimental conditions. In many instances for reasons other than the equilibration of faecal chromic oxide output with supplement intake such as changes in palatability between different feedblocks a much longer change-over period is preferential.

In many of the experiments in this thesis it was the intention to make a comparative assessment of individual intake variation for 'self-fed,' and 'hand-fed,' systems of giving additional nutrients to ruminants. The statistical term which is used to express variation within data is known as the coefficient of variation (CV) which has been defined earlier. The coefficient of variation embraces the total amount of variation within a set of data whether it be due to biological, analytical, technical or other causes. It would be important to know approximately what proportion of a particular CV could be reasonably assumed to be due to the interaction between the animal and method of giving nutrients (biological variation) and what proportion might be due to other causes inherent in the experimental technique (error variation).

The circumstances under which the chromic oxide technique for estimating individual intake using nylon mesh bags was evaluated differed in 2 major ways from how the technique was to be used in most of the experiments in the thesis. Firstly in the technique-evaluation experiments the sheep were individually penned and therefore movement was restricted, in the individual variation experiments the sheep were kept in a group situation with enclosure size varying from a few square metres to several hectares. In these situations the sheep had unrestricted movement and it is more likely that the total collection of faeces would be slightly less accurate. Also under field conditions it was rarely possible to empty the faecal bags twice daily when they appeared likely to overflow (a relatively full bag of faeces may be more likely to produce faecal losses). When the sheep were kept indoors it was easy to empty the faecal bags more than once daily if necessary and thereby minimise faecal losses.

The second major difference between the technique evaluation experiments and the application of the technique in the majority of the experiments in this thesis was that in a group system of giving nutrients, individual food intake must be irregular between days, whilst in Expts 1.1 and 1.2 both feedblock and hay (roughage) allocations were constant and in Expt 1.3 only the roughage allocation was offered ad libitum. It is possible that the CV for individual intake might be increased due to the irregular nature of dietary consumption.

Nevertheless the CV for both individual feedblock and estimated hay intake serve as a useful base line of minimum individual variation in a group of sheep when individually penned and individually given fixed allocations of chromic oxide containing food and roughage. It would be difficult to visualise a situation where a lower CV could be obtained for any group of sheep using the techniques described here unless there was no intake of chromic oxide-containing food whatsoever.

Expt 1.4. The relationship between the concentration of chromic oxide in a single grab sample of faeces and the estimated feedblock intake derived from the chromic oxide content of a 24-hour total collection

In many of the experiments carried out in this thesis it was not possible to obtain total collections of faeces. This was especially the case for cattle and when large groups of sheep in both the hill and lowland situation were used. In these circumstances an estimation of individual supplement intake could only be based on rectal grab samples and frequently it was possible to procure only a single sample per animal. The presence of chromic oxide in the faeces of individual animals would certainly allow a qualitative estimation of whether block was being consumed. However the exact concentration of chromic oxide in the faeces in a given situation depends upon several factors additional to those described in the Introduction as being inherent in the technique itself. These are the amount of chromic oxide-containing material consumed (e.g. feedblock, concentrate, cob), the amount of other material consumed (e.g. roughage) and the digestibility of the total diet.

The existence of a quantitative relationship between faecal chromic concentration and the intake of chromic oxide containing food would provide further very useful information; e.g. to compare the individual variation in intake when different types of supplementation are given.

In Expt 1.1 the use of rectal grab samples to estimate dietary digestibility with sheep (8) given hay and feedblock was shown to be as accurate as total faecal collection. The sampling procedure used relied upon 2 grab samples per day over either 3, 6 or 9-day periods. In the present experiment single grab samples from adult cattle were compared with a 24-hr total collection of faeces as estimates of individual variation in feedblock intake.

Materials and Methods

Twenty two, pregnant (Hereford cross) suckler cows weighing approximately 450 to 520 kg (at grass) were given two W291(76) feedblocks 14 days prior to the expected housing date (January 1977). The feedblocks contained 7·89 chromic oxide/kg DM. The total group intake of feedblock was recorded by daily weighing. The cows also received 4 bales of medium quality hay daily (4 kg/head) in addition to the poor grazing available.

At 12.00 hr on day 15 after introducing the blocks the cows were housed and tied in individual stalls in a byre. The total faecal output from individual cows over the 24 hr period (post housing) was collected directly from the dung channel. The cows were inspected frequently and any fresh faeces placed in plastic bags to minimise losses and contamination. At the end of the 24-hr period the total faecal output was weighed and subsampled according to Method 1 (page 71).

Additionally, 2 rectal grab samples were obtained from each cow at 14.00 hrs on the afternoon of housing and at 09.00 hrs on the following morning. The samples were dried and the chromium content was determined.

Results

The mean daily intake of feedblock by daily weighing was 0·86 ± 0·37 kg/head. The feedblock intakes estimated from single rectal grab samples and a 24-hr total collection of faeces are given in Table 6.

Table 6. Expt 1.4. Mean faecal oxide concentrations and feedblock intakes of cows

	Grab sample 14.00 hr	Grab sample 09.00 hr	24 hr total collection (12.00-12.00 hr)	
Mean faecal chromic oxide $g/10^4$ kg DM	1458	873	1082	378*
Range	118 - 4639	27 - 2637	28 - 3480	7 - 1352**
CV%	83.2	88.0	84.3	91.4

* Mean feedblock intake

** Range in feedblock intakes.

The individual faecal chromic oxide concentrations at 14.00 and 09.00 hr were positively correlated ($r = 0·93$ and 0.93) with feedblock intakes (Fig.1) estimated from the 24-hr collection. The relationships were highly significant ($P < 0·001$). The correlation ($r = 0·97$) between the faecal chromic oxide concentrations at each of the two separate grab samplings were also highly significant ($P < 0·001$).

The mean faecal chromic oxide concentration from the 14.00 hr grab sample (1458 $g/10^4$ kg DM) was 35% greater than the mean faecal chromic oxide ($1082/10^4$ kg DM) over the 24 hr collection. At the subsequent 09.00 hr sampling the faecal chromic oxide (873 $g/10^4$ kg DM) was 19% below the mean 24-hr value.

The estimated mean feedblock intake (378 g/head) was considerably lower than the mean intake determined by daily weighing.

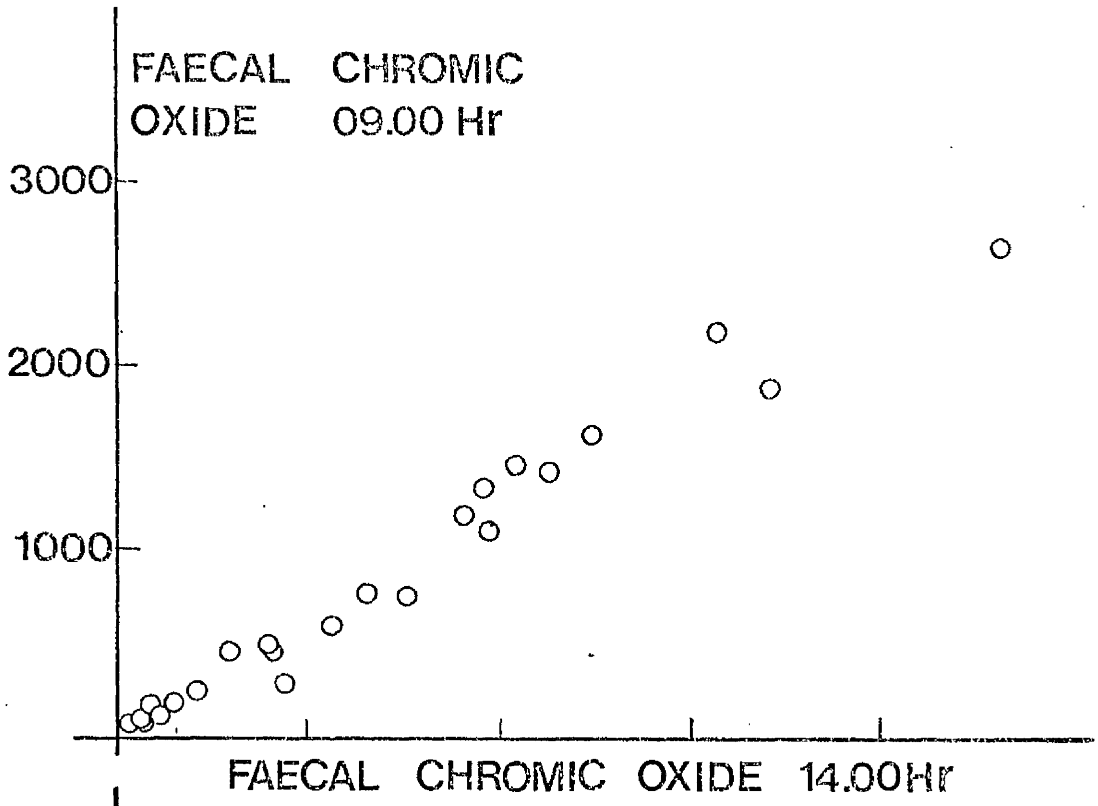
Discussion

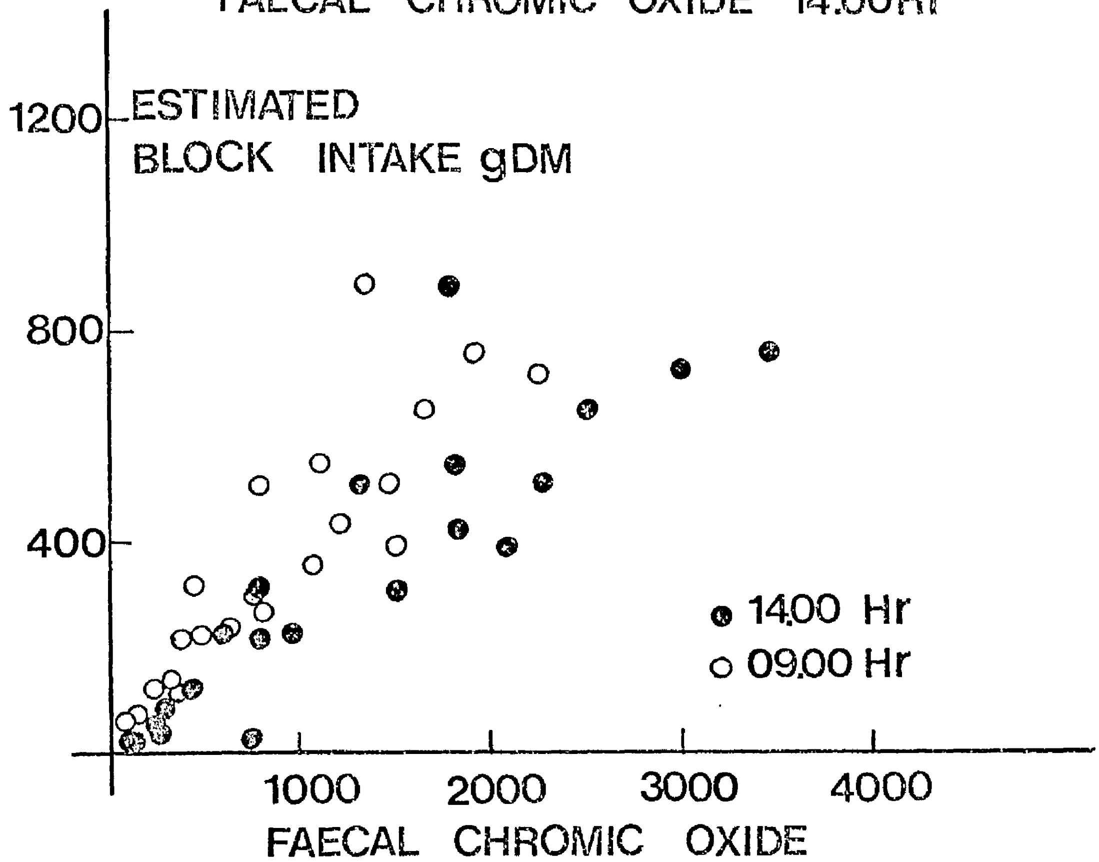
The low mean estimated feedblock intake using the 24-hr collection could be attributed to two causes. Firstly the feedblock intake over the 24-hr period immediately prior to housing (0·3 kg/head) was considerably below the mean (0·86 kg), recorded over the 14-day experimental period. Secondly it was shown in Expts 1.2 and 1.3 (Table 5) that sometimes within one and usually within 2 days after ceasing to give chromic oxide the output of chromic oxide in the faeces was about halved. This is consistent with the lower mean chromic oxide concentration at 09.00 hr (21 hr post housing) compared with either the overall 24-hr mean or the mean concentration at 14.00 hr (2 hr post housing). The low intake of chromic oxide over the day before housing and the cessation of giving chromic oxide would account for the discrepancy in estimated mean feedblock intake and feedblock intake over the experiment.

The coefficients of individual variation for either feedblock intake or mean faecal chromic oxide concentration agreed closely, reflecting the highly significant positive correlations between these parameters. Therefore it is reasonable to assume that the chromic oxide content of single rectal grab samples are useful indicators of relative intakes of chromic oxide containing foods. When it is possible to procure several grab samples (on one day or over a period) from each animal, increased accuracy is likely to be gained. Due to the diurnal variations in chromic oxide excretion discussed in the Introduction, it is essential that the grab samples are taken from all the animals in a group at approximately the same time. The faecal chromic oxide concentration of rectal grab samples by itself in no way allows an accurate absolute estimate of supplement intake to be formed. However an approximate estimate of absolute individual intake may be made if the total group intake is known; individual intakes may be

Fig.1a Expt 1.4 Relationship between faecal chromic oxide concentration ($g/10^4$ kg DM) in single rectal grab samples obtained at 09.00 and 14.00 hr.

Fig.1b Expt 1.4 Relationship between faecal chromic oxide concentrations ($g/10^4$ kg DM) in single rectal grab samples obtained at 09.00 and 14.00 hr and estimated feedblock intake from a 24-hr total collection.


FAECAL CHROMIC
OXIDE 09.00 Hr
3000
2000
1000
FAECAL CHROMIC OXIDE 14.00Hr


1200
ESTIMATED
BLOCK INTAKE gDM
800
400
14.00 Hr
09.00 Hr
1000
2000
3000
4000
FAECAL CHROMIC OXIDE

derived by apportioning the total intake according to faecal chromic oxide concentrations.

In many of the instances where one or more rectal grab samples have been used to measure individual variation in intake for different supplementation techniques (e.g. self-feeding v. hand-feeding) the interpretation of the faecal chromic oxide data and the resulting CV is difficult unless the same animals are used to evaluate both systems. A high faecal chromic oxide concentration may be indicative of a high consumption of chromic oxide-containing food, or a very low roughage intake resulting in a low faecal DM output and hence elevated faecal chromic oxide concentration. Therefore where grab samples were used to estimate relative feedblock intakes the individual variation intake was whenever possible compared with a concentrate control. This took the form of the same amount of DM as a concentrate pellet given in troughs with an adequate space allowance. These were a minimum of 40 and 80 cm for sheep and cattle, respectively, assuming access to both sides of the trough.

The implications and accuracy of using single grab samples to estimate individual variation in supplement intake are further discussed in Section 1. Expt 6.2.

II TIME LAPSE PHOTOGRAPHIC STUDIES

One of the objectives of this thesis was to record the behaviour of animals given feedblocks. In the indoor situation this was achieved by using a time lapse photography unit placed above the stock with an approximately 68 second interval between frames. The duration of each film was about 3 days. A flash unit was used to record behaviour during hours of darkness. The data obtained was analysed manually.

III THE DAILY WEIGHING OF FEEDBLOCKS

Throughout this thesis the group intakes from feedblocks were recorded by daily weighing using a 25 kg spring balance. In many instances the effect of climatic variables on the intake of feedblocks was studied which demanded the weighing of the blocks at a constant time each day. This was normally between 09.00 and 10.00 hr.

IV THE MEASUREMENT OF CLIMATIC VARIABLES

(i) Temperature

Temperature data were obtained using a maximum and minimum thermometer and mean daily temperature was recorded using a revolving thermograph.

(ii) Rainfall

The daily rainfall was recorded using a centimetre rain gauge situated at the premises of the Lower Clyde Water Board which was adjoining the Estate where the experiments took place.

V THE SAMPLING OF FAECES

Two alternative procedures were used for the sampling of faeces. When small numbers of animals were used (Method 1) in an experiment, the total daily faecal output from each individual was weighed fresh, dispersed on a tray and thoroughly mixed. A 10% subsample of the fresh output for each day was bulked together to form a composite sample for the required period of collection. The resulting composite samples were then analysed for DM and other relevant parameters.

When large numbers of animals were used (Method 2) the total fresh daily faecal outputs for each individual were grouped together over the desired number of days in a large polythene bag. The bag containing the total output of faeces over the collection period was weighed and the contents placed in a tray, about 1·0 x 1·0 x 0·2 metres, and mixed thoroughly. A representative subsample of faeces was obtained for DM and other relevant analysis.

A comparison between the two methods of faecal sampling was carried out with 32 sheep (ewes). The faeces from 16 ewes were sampled according to Method 1 and faeces from the other 16 ewes according to Method 2. The ewes had been given a chromic oxide containing feedblocks (CSE) for a 14-day period before faecal collection commenced. There was no significant difference in calculated feedblock intake as determined by the mean daily faecal DM output and their chromic oxide contents for the two sampling methods.

VI MEASUREMENT OF THE DIGESTIBILITY COEFFICIENTS OF FEEDBLOCKS

In several experiments in this thesis a comparison of providing similar amounts of digestible nutrients in either a feedblock or concentrate form was made. This required a knowledge of the digestibility coefficients for the feedblocks used. Several problems arose in the in vivo determination of digestibility coefficients; these were particularly severe for the supplement-type blocks which are intended to form only a small proportion of the total DM in the diet.

As demonstrated earlier in this thesis, when feedblocks are given alone digestive upsets are likely to occur even for the higher intake substitute-type feedblocks. Therefore any digestibility determination made on feedblocks must involve the digestibility by difference technique. Reliable digestibility estimations of most foods can be derived in this manner but especially with feedblocks several extra difficulties are involved. These include the following;

(i) Feedblocks are purposefully designed to restricted voluntary intake and give a 'self-help,' system of feeding. The nutritionist is therefore faced with a dilemma in what quantity of any feedblock can be given without causing refusals or digestive disturbances and at the same time provide a meaningful increment above the basal ration to facilitate accurate measurement of feedblock digestibility. This can usually only be determined by trial and error.

(ii) In practice feedblocks may be ingested little and often but in digestibility trial studies such a pattern of giving food is often impractical and meal feeding has to be adopted. Therefore any possible interaction between block ingredients and frequency of intake on diet digestibility are not assessed.

(iii) Feedblocks are often specifically formulated to increase the digestibility of other dietary components such as poor quality roughages. Reliable digestibility estimates using the difference technique require the use of a basal ration which ideally maintains a constant digestibility when the increment of food to be evaluated is given. This means that the basal ration must be of sufficiently high quality as to preclude any associative influence between the basal and test foodstuff. A further complicating feature where feedblocks are concerned is that due to the considerable salt inclusions in some blocks, water intake is likely to be high and excessively soft faeces may result. Therefore another requirement of the basal ration is that it should contain sufficient fibre to ensure that faeces are manageable for quantitative faecal collection. This may be incompatible with fulfilling the criterion of a high quality basal ration. The choice of basal ration is therefore of utmost importance in determining the digestibility of feedblocks by difference.

For the substitute-type feedblocks the most satisfactory basal ration employed was approximately 1 kg (fresh matter) of moderate quality dried grass cubes (142 g CP, 221 g CF, 25 g EE, 76 g Ash/kg DM). When given to mature wethers this allocation was readily consumed together with increments of feedblock material between 200 to 500 g. In most cases the faeces produced from these diets were reasonably well pelleted, enabling quantitative collections of faeces to be made with confidence. The digestibility estimates obtained in this manner for several different types of substitute-feedblock are given in Table 7. The procedure for these estimations was to give the sheep (normally 4/treatment) in metabolism crates grass cubes alone for 17 days followed by a further 17 day period when the grass cubes and feedblock material were given. Faeces were collected over the final 7 days of each period. The diets used were given in 2 approximately equal portions at 08.00 and 16.00 hr.

None of the basal rations examined appeared to be satisfactory for evaluating digestibility of supplement-type feedblocks by the difference method. One proprietary supplement-type feedblock was completely refused by wethers when given as 150 g feedblock DM/kg of

Table 7. Estimated digestibility (DE MJ/kg, DCP g/kg and DOM g/kg contents DM basis) for several substitute-type feedblocks, using the difference technique and a basal ration of dried grass cubes

Feedblock	CSE	W290(74)	W290(76)	W291(74)	W291(76)	Dried grass cubes
No. of sheep	5	3	4	3	4	12
Feedblock g	212	326	443	332	446	800 to 900
Included salt g	31	19	26	12	13	-
Digestibility % DM	73.8±3.5	66.8±0.6	63.2±1.8	58.7±0.8	65.7±4.2	72.2±0.7
OM	76.7±3.2	nd.	79.7±3.2	nd.	80.7±3.1	72.6±1.4
N	87.6±3.0	71.5±3.5	82.2±1.5	77.7±1.8	84.5±5.2	64.9±0.9
Energy	78.2±4.6	75.7±1.8	80.4±3.8	79.1±4.3	83.1±2.5	70.4±0.7
Calculated DE	11.4	9.7	10.2	10.4	11.4	13.0
Calculated DCP	149	173	168	176	167	92
Calculated DOM	585	nd.	591	nd.	604	671

total diet. In one experiment it was hoped to characterise the nutritive value of a supplement feedblock (RHE) and compare the giving of equal amounts of supplementary digestible crude protein and energy as either feedblock or concentrate material. When dried grass cubes were used as the basal ration, the maximum amount that could be given and still ensure that the feedblock inclusion (203 g DM) would be consumed was 880 g DM of grass cubes (Trial A). Unless receiving food at a level well below appetite, the sheep were most reluctant to consume the supplement feedblock material given. When the procedure for measuring digestibility was carried out as for the substitute-type feedblocks the sheep scoured excessively and although faeces were collected quantitatively using polythene linings in rubberised canvass faecal bags the results obtained (Table 8) appeared anomalous. There was considerable variation between individual sheep in digestibility estimates, particularly for N digestibility, reflected in the high SE of the mean. The computed ME value for RHE (DE x 0·81) was 5·19 MJ/kg which was far below the manufacturers claimed value of 8·6 MJ/kg.

When a second digestibility trial (Trial B) was conducted using a different basal ration of 664 g DM composed of the following (482 g distillery siftings, 326 g barley, 121 g cottonseed meal, 18 g dicalcium phosphate and 18 g calcium carbonate/kg) plus 251 g of RHE, similar results (Table 8) were found. It was hoped that the inclusion of more CF in the basal ration from the siftings (with 400 g CF/kg) would alleviate the scouring problem but no improvement was found. Therefore the nutritive value of RHE and supplement feedblocks in general could not be accurately characterised in isolation, which was inconvenient from an experimental viewpoint but not really surprising because of their intended use as low intake supplements for poor quality roughages. The critical evaluating test for supplement feedblocks is their effect on roughage consumption and digestibility of the total diet

Table 8. The estimation of digestibility (DE MJ/kg, DCP g/kg and DOM g/kg) for RHE feedblocks by difference using two types of basal ration (Mean values ± SE)

Digestibility %	Trial (A) 3 sheep 880 g DM dried grass cubes (Basal ration)	880 g DM dried grass cubes + 203 g DM RHE	RHE By Difference	Trial (B) 4 sheep 664 g DM Basal ration	664 g DM Basal ration + 251 g DM RHE	RHE By Difference
DM	70.3 ± 1.0	66.6 ± 0.8	50.6 ± 2.3	62.5 ± 1.3	56.9 ± 0.7	42.2 ± 2.3
OM	71.4 ± 1.0	68.6 ± 0.80	50.9 ± 9.7	65.6 ± 1.1	59.8 ± 0.8	38.6 ± 4.0
N	63.5 ± 1.4	57.9 ± 1.8	42.3 ± 12.3	56.4 ± 4.3	62.3 ± 1.6	71.6 ± 4.4
Energy	68.3 ± 1.3	66.8 ± 1.3	56.3 ± 2.3	65.6 ± 1.0	62.5 ± 1.7	49.5 ± 5.8
DE MJ/kg DM	-	-	6.41	-	-	5.63
DCP g/kg DM	-	-	74	-	-	126
DOM g/kg DM	-	-	340	-	-	257

when it is principally composed of roughage.

The results obtained in the two small scale digestibility Trials A and B partly stimulated the much more detailed investigation of the ingredients of Rumevite feedblocks later in this thesis. The proportion of RHE in the total diet for trials A and B was 187 and 274 g/kg diet DM, respectively. The inclusion of salt (123 g/kg DM) in RHE meant that for the two trials the intake of salt was 25 g and 31 g from the feedblock, respectively. However when the substitute-type feedblocks CSE (145 g salt/kg) and W290(74) (60 g salt/kg) were given in a digestibility trial, the salt intakes from the feedblocks (Table 7) were similar to RHE. In these trials no scouring occurred and apparently valid digestibility data was accumulated. Therefore it appeared unlikely that the salt inclusion per se in RHE was alone responsible for the digestive disturbances produced. It is possible that some other ingredient in RHE induced the animals to drink more water and thus produce very soft faeces. Most of the ingredients of RHE e.g. urea, cereals etc. are also included in the substitute-feedblocks apart from EC feed (the feedblock hardening agent) which forms approximately a quarter of the Rumevite block. The effect of EC feed on digestibility is examined in detail in Section 4 of this thesis.

SECTION 1

INDIVIDUAL VARIATION IN FEEDBLOCK INTAKE AND COMPARISON WITH OTHER TYPES OF SUPPLEMENTATION

Introduction

A series of advantages have been proposed for the giving of supplementary nutrients on a 'self-help,' system such as is possible when feedblocks, liquids or salt-containing concentrates are used. It is implied that because crowding and bullying are largely eliminated when 'self-help,' supplements are given a more uniform type of supplementation may be effected than when stock are 'hand-fed' using troughs. Some of the advantages claimed for 'self-fed,' supplements, have been summarised by Weir and Torrell (1953).

(a) Stock do not have to be given the supplements daily.

(b) Each animal has an opportunity to take as much supplement as it desires.

(c) The animal can increase its intake as the supply of other food decreases.

(d) Fewer, if any, feed troughs are needed.

(e) All the animals in a group do not have to be present at the feeding trough at the same time to get their fair share of supplement.

Feedblocks are also claimed to be of particular use in encouraging 'shy-feeders,' such as 2-year-old sheep (gimmers) to make use of supplementary feed in competition with older sheep.

Conversely, because by definition feedblock intake is limited by physical hardness and/or unpalatability of feedblock ingredients some individuals may be reluctant to consume block material, while other more greedy animals might consume disproportionately large quantities of block material. The intake variation might then be greater than for trough given food. No publication exists where feedblock and trough supplementation systems have been critically compared in terms of individual intake variation.

The individual variation resulting from feedblock supplementation has been the subject of only 3 studies; Beames (1963), and Pearce and Raven (1973) with cattle and Beames and Morris (1965) with sheep. The results of these experiments have already been reviewed in the introduction to this thesis. Only very small numbers per group were used particularly for cattle.

The individual variation from hand-feeding of supplementary nutrients using troughs under housed conditions has been studied by Foot and Russel (1973) using barren sheep and Foot, Russel, Maxwell and Morris (1974) using pregnant ewes. Foot and Russel (1973) found that there can be a two-fold difference in intake of pelleted food by individual animals in the same group. They also concluded that the physical form of the diet was of great importance in determining the magnitude of variation for food intake in a group situation. The CV for individual variation in hay intake (13%) was consistently below that for variation in concentrate intake (36%).

Foot, Russel, Maxwell and Morris (1974) found that individual concentrate intakes were most variable (CV 24 to 51%) when the daily group allowance was small (96 g DM/sheep) but variation decreased (CV 13 to 21%) when the amounts of concentrates given increased, to contribute up to 47% (435 g DM/sheep) of the total digestible DM intake. When mature and two-year-old ewes in their first pregnancy were penned together, the younger sheep were at no disadvantage in terms of amount of concentrate consumed. Some multiparous ewes however were less competitive and consumed inadequate amounts of concentrates to meet nutrient requirements (principally energy) during the critical 6-week period prior to parturition. It was concluded that the giving of supplementary nutrients to pregnant ewes as concentrates in troughs could be a very wasteful and imprecise method.

There is no report where the effect of trough space allowance per animal on individual supplement intake has been studied. Arnold and Miller (1974) gave oats (450 g/day) at space allowances from 4 to over 50 cm to sheep at grazing. Below 12 cm/sheep considerable disturbance occurred and some sheep stopped competing for feed and became non-feeders. The number of non-feeders at a particular trough length was determined on the first day that the spacing was imposed. The disposition of some sheep to compete strongly, day after day, did not wane and no gradual increase in the proportion of non-feeders was observed. This is consistent with the principle that the dominance ranking of animals confronted with a new situation is established quickly and thereafter remains stable. In a flock of Merino wethers of mixed age group the 1-year-old and 7-year-old sheep were the least competitive. Arnold and Miller (1974) suggested a minimum trough space allowance of 16 cm when daily grain supplements are given to grazing sheep.

There appears to be little justification to suggest that feedblocks are superior in terms of uniformity of intake within a group, to hand-fed concentrates given in troughs. In previous experiments the amount of variation for both types of supplementation has been considerable but no controlled comparative studies have been made. A series of experiments were therefore undertaken in the present study to compare the extent of individual variation from feedblocks and trough supplements for both sheep and cattle under a variety of conditions. The initial experiments were performed with housed sheep to obtain maximum control over the experimental conditions. A concurrent behavioural investigation using time lapse photography equipment was also undertaken in the first of these experiments.

A The individual variation in voluntary food intake within groups of mature housed ewes offered feedblocks or concentrates in competitive and non-competitive situations

Materials and Methods

Thirty two, barren, Greyface (Border Leicester ♂ x Scottish Blackface ♀) ewes ranging in live weight from 51 to 78 kg were divided into 2 groups (A and B) according to their live weight and dental status. The ewes had some limited previous experience of consuming feedblocks. At the onset of the trial (November 1974) most of the ewes possessed a full compliment of permanent incisor teeth which in several cases were long and loose. The ewes were housed in an open fronted building and were bedded on sawdust.

Experiment 2.1. Ewes receiving feedblocks in a competitive situation

In this experiment of approximately 7 weeks duration, group A ewes had continual access to a 'high intake,' feedblock (W290(74)). Group B ewes were offered a lower intake (i.e. harder) feedblock (W291(74)).

Typical chemical compositions of these blocks are given in Table 1. Both feedblocks contained chromic oxide, 2·48 and 2·40 g/kg DM for the W290(74) and W291(74) blocks, respectively. The mean daily group intakes on a fresh matter basis were monitored by weighing and residues were removed when less than 4 kg of block material remained and a new feedblock then substituted. Often the level of intake attained for (W290(74)) required that a new block be introduced daily. Ad libitum, poor quality hay (53 g CP, 41 g Ash, 394 g CF, 11 g EE, 501 g NFE/kg DM) was given to both groups in Norwegian box-type feeders. The amounts of hay introduced were recorded.

The ewes were equipped for quantitative faecal collection with harness and nylon mesh bags. Faeces were collected from the ewes

8 to 14 and 28 to 34 days after the initial introduction of the blocks. Faeces were sampled according to Method (1) (page 71). A 4-day collection of faeces over days 8 to 11 and 28 to 31 was also made by retaining a further 10% of the total fresh output, enabling individual feedblock intakes to be computed according to the chromic oxide recovered over both 7 and 4-day periods.

After the collection (days 28 to 34) had been completed, a change over was effected with group A ewes transferred to the W291(74) feedblock and group B ewes to W290(74). Faeces were collected from the ewes over days 8 to 14 and 8 to 11 to give 7 and 4-day composite samples, respectively.

A time-lapse photography unit was sited on a platform above the sheep focused on both feedblocks. Several films each of 72 hours duration, with an interval of approximately 68 seconds between frames were obtained. These films together with a 24-hr manual observation study were analysed with the intention of establishing the feeding and resting behaviour of the sheep with special emphasis on the number of visits, the duration of each visit and the total time spent at the feedblocks for individual sheep during any 24-hr interval. To facilitate identification of individual ewes a large plastic number plate was attached to the harness straps on the back of each ewe.

<u>Experiment 2.2. Ewes receiving broken feedblock material in troughs</u>

In this experiment, group A ewes were given 0·83 kg DM/head/day of W290(74) block material in a ground form, equivalent to their mean daily intake from intact feedblocks in Expt 2.1. This allocation was given once daily in troughs with a space allowance of 41 cm/sheep. In practice, the quantity of material offered proved unpalatable to the sheep for rapid consumption and frequently material remained uneaten 8 to 10 hr after introduction, although all was consumed in 24 hr.

Group B ewes received 0·25 kg DM/head/day of W291(74) block material under similar experimental conditions to group A ewes. This level of feedblock allocated was consumed rapidly within 2 to 3 minutes without any interruption of feeding behaviour. Hay was on ad libitum offer as for Expt 2.1 and total faecal collections were obtained from the ewes between 8 to 14 days, following a 7-day introductory period.

Experiment 2.3. Ewes receiving a barley-vegetable protein concentrate in troughs

The same experimental procedure was conducted as in Expt 2.2 except that an equivalent amount of DM in the form of a barley-vegetable protein concentrate pellet (143 g CP, 35 g Ash, 64 g CF, 16 g EE and 742 g NFE/kg DM) was given instead of the broken feedblock material. Chromic oxide (2·77 g/kg DM) was included in the pellets. It was originally intended to give 2 levels of the concentrate, commensurate with the mean DM intakes from the intact feedblocks. These were 0·83 kg DM and 0·25 kg DM/head/day for groups A and B, respectively. However digestive disturbances were produced in several group A ewes and these had to be removed from the experiment, and the 0·83 kg DM allocation was discontinued. After the period when 0·25 kg was given the group B ewes were given 0·50 kg DM/head/day to estimate the individual variation in intake at a higher level of concentrate allocation.

Experiment 2.4. Ewes receiving feedblocks in non-competitive situations

In Expt 2.4 both groups of ewes were individually penned (2 m x 1·5 m) for 14 days. Hay and water feeders were situated at the front of the pen with halved feedblocks sited at the rear. The ewes were given W291(74) (group A) and W290(74) (group B). Chopped hay of similar composition to that given in the previous experiments was on offer ad libitum. The amount consumed per ewe was recorded between days 8 to 14. Individual consumption of water was recorded over the same period. The halved feedblocks were weighed daily and replaced when less than 1 kg of fresh material remained. A total faecal collection was made over the final 4 days of the experiment. Thus the estimated feedblock, hay and total DM intake obtained by both weighing and faecal sampling could be compared for individual sheep.

Dental status of ewes

A reassessment of dental status of the ewes was conducted upon completion of the experiments. The ewes were subjectively assigned to 5 dental categories (A to E) where category A sheep possessed a full complement of permanent incisor teeth in reasonable condition and category E ewes showed advance signs of dental depreciation, characterised by the absence of critically positioned incisor teeth, gum erosion and gap development. Categories B, C and D were intermediate in nature with B slightly worse than A but still considered of little handicap. Category D was slightly better than E whilst sheep in category C were adjudged to possess teeth showing signs of average depreciation for these ewes.

Computation of the data

In all experiments the individual intakes of feedblock or concentrate were calculated from the total faecal chromic oxide output per ewe over the various collection periods. The DM digestibilities of the concentrates (81·0%), hay (51·6%) and feedblocks (65·3% and 58·7% for W290(74) and W291(74) respectively) were separately evaluated using groups each of 4 mature Greyface wethers in metabolism cages. The technique used for the feedblock is described on page 73. An approximate estimation of individual voluntary hay intakes by the sheep was made by apportioning faeces according to the indigestibility coefficients of the feedblock or concentrate dietary component and the remaining faecal DM was attributed to the hay intake. This estimation assumes no associative interaction between the dietary constituents, particularly a possible improvement in hay digestibility when supplementary nitrogen is given. In an attempt to quantify any interaction, a digestibility trail was carried out using 12 mature wethers given diets containing widely differing proportions of hay and concentrate. When 625 g DM of hay was given with 256 g DM of concentrate (a ratio of 2·4 : 1) the mean DM digestibility of the hay increased from 51·6 to 54·2%. When 268 g hay DM plus 598 g concentrate DM (a ratio of 1 : 2·2) the DM digestibility of the hay increased significantly ($P < 0{\cdot}05$) to 62·2%.

Results

Experiment 2.1

In Expt 2.1 the mean daily intake of both feedblocks increased gradually over the initial 35-day period. The overall (i.e. 35 days) mean DM intakes of W290(74) and W291(74) were 834 ± 34 and 255 ± 19 g for group A and B, respectively. Group B ewes consumed significantly ($P < 0{\cdot}01$) more hay (1224 ± 34 g) than group A ewes (1054 ± 51 g).

After the blocks were changed over the intake of W291(74) by group A ewes (327 ± 50 g) was significantly ($P < 0{\cdot}01$) greater than the intake attained by group B ewes for the same block (129 ± 20 g) over a similar initial 14-day period. It was also in excess of the mean consumption of W291(74) by group B ewes over the total 35-day period. However the intake of W290(74) by group B ewes (625 ± 45 g) over 14 days was not significantly different from that of group A (682 ± 50 g) over their initial period of access to the block. The hay DM intakes for groups A and B after the change over were not significantly different (1097 ± 51 and 1003 ± 26 respectively).

Table 9 contains details of the individual variation in voluntary intake of feedblocks, hay and total DM for the ewes in Expt 2.1. The CV for the voluntary intake of W290(74) and W291(74) for group A ewes tended to be reduced when a 7-day collection was used.

Table 9. Expt 2.1. Voluntary feedblock, hay and total DM intakes and respective CV for individual intake variation

	Softer W290(74) block						Harder W291 (74) block					
	GROUP A				GROUP B		GROUP B				GROUP A	
	Days 8-14		Days 29-35		Days 8-14		Days 8-14		Days 29-35		Days 8-14	
Collection period (days)	4	7	4	7	4	7	4	7	4	7	4	7
Feedblock intake g DM/day	548	563	770	764	553	512	83	72	175	208	195	260
CV%	25.4	25.7	29.0	20.6	53.8	39.5	51.4	67.1	47.8	49.1	47.8	34.2
Hay intake g DM/day	1031	1020	922	954	831	900	1034	1046	953	934	905	1014
CV%	21.1	21.1	27.7	25.3	26.2	30.2	29.2	29.2	32.1	34.2	20.0	21.7
Total intake g DM/day	1579	1583	1692	1718	1384	1411	1117	1118	1128	1142	1100	1274
CV%	18.2	17.0	20.1	18.9	28.8	27.8	26.5	27.4	26.8	28.9	14.2	17.2

However, the CV was greater for group B ewes when given the harder W291(74) block over a 7-day collection. If the CV derived from a 7-day collection is reasonably assumed to reflect a more accurate indication of block intake variation, two trends become apparent. One is the greater CV for both group A and B sheep on the harder W291(74) feedblock. The CV was significantly ($P < 0.01$) lower (25·7%) over days 8 to 14 for group A ewes on W290(74) compared with group B ewes given W291(74), (CV = 67·1%). Over the corresponding 4-day collections the difference in variation was also significant ($P < 0.05$). The second feature of interest is the greater CV for feedblock intake exhibited by group B ewes over group A ewes irrespective of feedblock-type. The expression of feedblock intakes in terms of unit sheep live weight did not remove any of the variation inherent in the groups and in some cases in fact increased variation.

The CV for the estimated hay intakes were in most cases considerably less than those for feedblock intake, particularly for the harder W291(74) feedblock; with group A ewes (4-day collection) the CV for hay intake (20%) was half that for block intake (48%). There were no significant differences in estimated hay DM intake during the collection periods. When the hay intakes were expressed in terms of unit sheep live weight, the mean CV for all 12 collections was 22·8% which was significantly lower ($P < 0.05$), than when hay intake variation was expressed in absolute terms (mean CV = 26.5%). There were no significant correlations between hay and feedblock intakes. Total DM intakes were significantly higher ($P < 0.001$) for group A ewes given the softer W290(74) feedblock than for group B ewes given the harder W291(74) feedblock, reflecting the differences in feedblock consumption. The CV for total DM intake was in nearly every collection below that for hay intake.

Table 10 gives the results of the behavioural studies conducted in

Table 10. Behavioural study of housed sheep given feedblocks

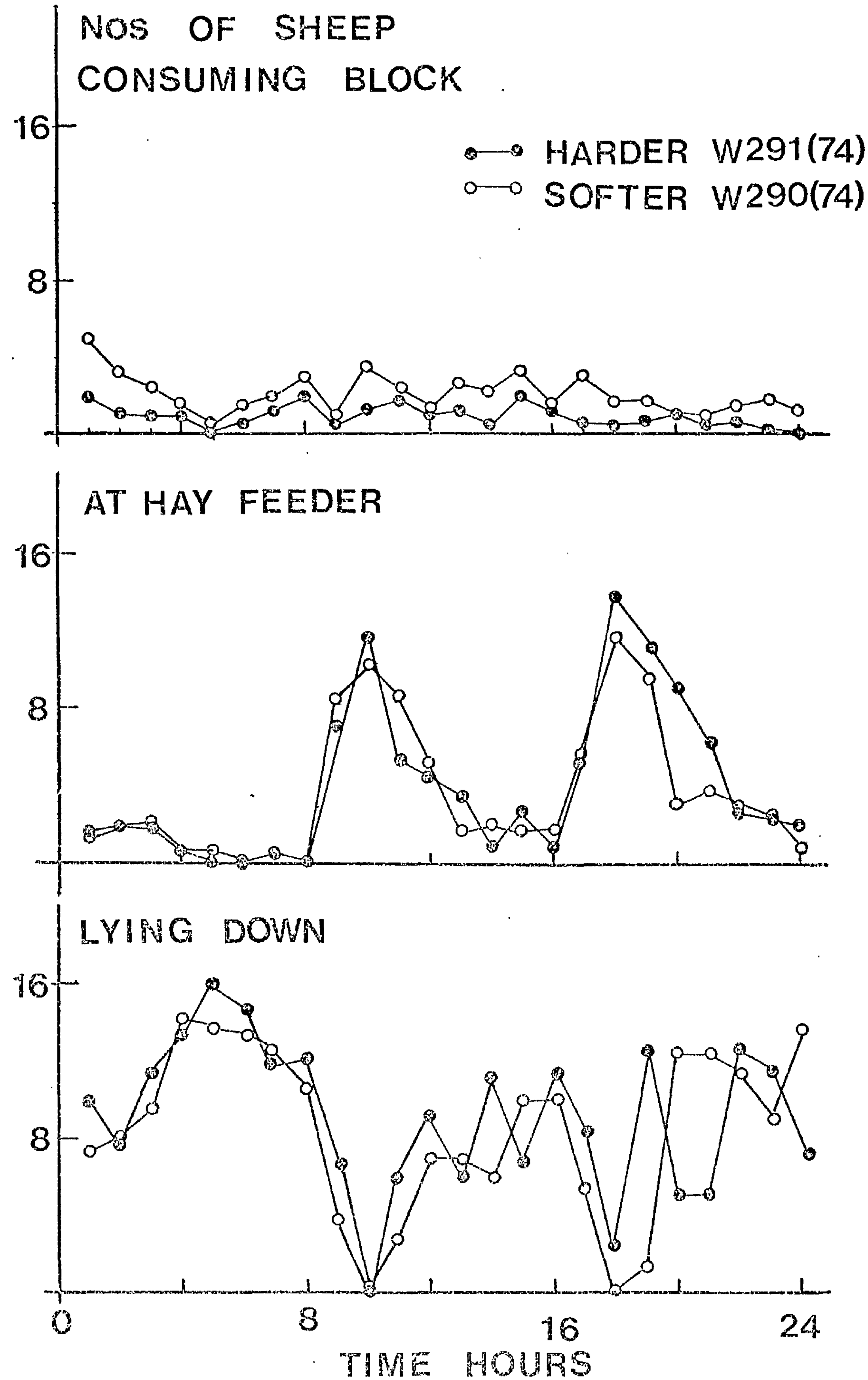
Mean 16 sheep/group

Time lapse photography

Feedblock		Softer W290(74)	Harder W291(74)	SED	Level of sig
Visits/day		37(23.7)+	19(56.0)	3.5	***
Visits/day > 68 secs		25(27.0)	10(64.1)	2.3	***
Time at block mins/day		175(30.6)	52(61.6)	15.6	***
Mean duration of a visit (mins)		4.9(31.9)	2.6(22.2)	0.37	***
Voluntary feedblock intake g DM/visit		15.3(19.6)	5.1(49.1)	0.98	***
Voluntary feedblock intake g DM/visits > 68 secs		23.1(19.3)	11.0(65.8)	2.13	***
Rate of feedblock intake g DM/min		3.3(27.0)	2.0(59.2)	0.37	**
% of a 24 hr period at feedblock		12.2(30.9)	3.6(61.6)	1.00	***
Manual observations					
% of a 24-hr period at feedblock	2400-0600	14.1	6.0		
	0600-1200	13.3	8.9		
	1200-1800	15.1	5.2		
	1800-2400	7.8	1.8		
Overall Mean		12.6	5.5	0.25	***
% of a 24-hr period at hay feeder	2400-0600	6.3	11.2		
	0600-1200	33.9	31.2		
	1200-1800	24.2	27.1		
	1800-2400	22.4	34.1		
Overall Mean		21.7	25.9	1.09	**
% of a 24-hr period lying	2400-0600	68.7	75.5		
	0600-1200	39.7	47.9		
	1200-1800	39.4	44.4		
	1800-2400	63.4	52.4		
Overall Mean		52.8	55.0	-	NS

+ CV%

Fig.2 Expt 2.1 The typical behavioural pattern of two groups each of 16 sheep consuming either soft (W290(74)) or harder (W291(74)) feedblocks indoors during a 24-hr period. Hay was introduced at 08.00 and 16.00 hr each day.


NOS OF SHEEP
CONSUMING BLOCK
HARDER W291(74)
SOFTER W290(74)
AT HAY FEEDER
LYING DOWN
16
8
16
8
16
8
0
8
16
24
TIME HOURS

Expt 2.1. Because of the vast amount of data generated by the time lapse photography studies and the time required to analyse this, only one film was analysed in full. The results of a typical 24-hr period are given in Table 10. The ewes given the softer W290(74) feedblock made 2 x the number of visits, stayed 2 x longer and consumed feedblock nearly 2 x as rapidly as the ewes given the harder W291(74) feedblock. The voluntary intake of the W290(74) per visit was 3 x that for the W291(74) feedblock. Most of the visits to the harder W291(74) feedblock (50%) were under 1 minute, compared with 33% for the softer W290(74), whilst only 4% were in excess of 8 minutes in duration compared with 20% for W290(74). The percentage of any 24-hr period spent at the feedblocks, as calculated for the time lapse photography studies (12·2 and 3·6 for W290(74) and W291(74), respectively) agreed closely with the results from the manual observation study. Ewes given the harder W291(74) feedblock spent significantly ($P < 0 \cdot 01$) more time at the hay feeder which is consistent with their significantly higher hay intake during the Expt 2.1. The distribution of visits to the respective feedblocks, hay feeder and time spent lying down throughout a 24-hr period are presented graphically in Fig.2.

The correlation between time spent at the block and number of visits/day was highly significant ($P < 0 \cdot 001$) for the harder W291(74) feedblock but not significant for W290(74). The voluntary intake of softer W290(74) feedblock was significantly correlated ($P < 0 \cdot 01$) with time spent at the block and number of visits/day ($P < 0 \cdot 01$) but not significantly correlated with mean duration of each visit. The voluntary intake of the harder W291(74) was significantly correlated ($P < 0 \cdot 01$) with time spent at the block and number of visits ($P < 0 \cdot 05$) but again not with mean duration of each visit.

There was considerably more variation for group B ewes given the harder W291(74) block in all the behavioural parameters measured, except for mean duration of each visit.

Upon completion of Expt 2.1 the mean live-weight gains for the ewes were 2·3 and 1·0 kg for groups A and B, respectively.

Experiments 2.2, 2.3 and 2.4

The mean intakes of feedblock, concentrate, estimated hay and total DM intakes and their respective coefficients of variation are given in Table 11. There was slightly more variation in intake of the softer W290(74) (CV = 29 v. 21%) for group A ewes, consuming the feedblock in meal form given in troughs, than from the intact feedblock (Expt 2.1 Table 9). When group B ewes were given the harder W291(74) in Expt 2.1 (Table 9) the mean intake of 208 g dm/day produced a CV of 49% but when the feedblock material was given in a broken form in troughs (mean intake 220 g DM/day) the resulting CV was considerably reduced (33%).

In Expt 2.3 the CV for group B ewes consuming a mean 206 g DM/day of concentrates (33%) was also considerably below the value for an equivalent amount of DM consumed from the harder W291(74), (49%). When group B ewes were given intact W290(74) the CV (40%, Table 9) was similar for an approximately equal DM intake (512 v. 440 g) from trough given concentrates (37% Table 11). There was no difference in CV (33%) for giving similar amounts of broken W291(74) or concentrates in troughs (Expts 2.2 and 2.3 respectively).

In Expt 2.4, ewes in group A consumed 3·4 x more of the harder W291(74) when the blocks were given individually, than in the group situation (663 v. 195 g, Table 8) in Expt 2.1. Group B ewes consumed 1·4 x more of the softer W290(74) when individually penned than in the group situation (Tables 9 and 11). There was now no significant difference in mean intake from the two different feedblocks when given to individually penned sheep. The mean feedblock intakes determined by daily weighing over the 14-day duration of Expt 2.4 were not significantly different and individual intakes correlated very closely (r = 0·94) with the respective values calculated by referring to chromic

Table 11. Expts 2.2, 2.3 and 2.4. The mean (16 sheep) intakes of feedblock, concentrate, hay and total DM and their respective CV

	Expt 2.2		Expt 2.3		Expt 2.4			
	Feedblock meal in troughs		Concentrates in troughs		Feedblocks given individually			
	Softer W290(74)	Harder W291(74)	0.5 kg	0.25 kg	Softer W290(74) Faecal sampling	Softer W290(74) Weighing	Harder W291(74) Faecal sampling	Harder W291(74) Weighing
Sheep group	A	B	B	B	B	B	A	A
Collection (days)	7	7	7	7	4	14	4	14
Supplement intake g DM/day	724	220	440	206	795	787	663	640
CV%	29.0	33.2	37.4	33.4	35.1	28.1	47.5	30.4
Hay intake g DM/day	886	839	662	840	779	768	831	864
CV%	22.3	32.4	44.6	40.0	28.0	20.4	16.9	15.2
Total DM intake g/day	1610	1059	1102	1046	1573	1555	1494	1504
CV%	14.1	26.0	31.5	35.2	27.3	20.3	21.1	14.4

oxide recovery over the 4-day sampling period. The CV for variation in intake of the softer W290(74) (54% Table 9) in the group situation was greater than when the group B ewes were individually given feedblocks (35%). There was no difference in variation for group A ewes when the harder W291(74) feedblock was given in groups or individually. The water consumption for ewes in groups A and B was $5{\cdot}3 \pm 0{\cdot}27$ and $5{\cdot}8 \pm 0{\cdot}47$ litres/day for the W291(74) and W290(74) feedblocks, respectively. This difference was not significant.

The estimated hay intake for Expts 2.2, 2.3 and 2.4 tended to be lower than for Expt 2.1. In particular when the 0·5 kg/head DM quantity of concentrate was given, mean hay intakes (662 g DM) declined and CV in hay intake increased (45%), to become greater than the CV for concentrate intake (37%). In Expt 2.4 the estimated hay intake data agreed closely with the weighed inputs over a 7-day period, there was also a very close correlation ($r = 0{\cdot}76$) for individual hay intakes computed by the two methods.

Dental status

A comparison of the intakes of W290(74) and the W291(74) feedblocks for ewes with dental status in categories A + B v. D + E was carried out using the individual intake data from Expt 2.1. Collection periods were used where the intakes of both A and B ewes were approximately similar for the respective blocks. The effect of dental status on the consumption of the trough given supplements in Expts 2.2 and 2.3 was examined. The results obtained for these comparisons are presented in Table 12. The number of ewes in categories A, B, C, D and E were (8, 2, 3, 2 and 1) and (5, 1, 3, 2 and 5) for groups A and B, respectively.

When the intakes of the harder W291(74) for category (A + B) ewes were combined for both groups of sheep a significantly greater ($P < 0{\cdot}001$) intake was recorded than for ewes in categories (D + E). For the softer W290(74) feedblock the difference was still significant ($P < 0{\cdot}05$) but at

Table 12. Expts 2.1, 2.2 and 2.3. The effect of dental status on the intake of feedblocks and supplements

	Category A+B	Category D+E	SED+	Level of sig
Self-fed				
Expt 2.1				
W291(74)				
No of sheep	16	10		
Mean intake g DM/day	282	141	10.4	***
W290(74)				
No of sheep	16	10		
Mean intake g DM/day	586	415	66.6	*
Hand-fed (troughs)++				
Expt 2.2				
Broken W291(74)				
No of sheep	6	7		
Mean intake g DM/day	212	210	-	NS
Expt 2.3				
0.25 kg concentrates/head				
No of sheep	6	7		
Mean intake g DM/day	185	232	-	NS
0.5 kg concentrates/head				
No of sheep	6	6		
Mean intake g DM/day	450	505	-	NS

+ Standard error of the difference between 2 means.

++ Trough space allowance 41 cm/head

a lower level. When the ewes were given trough supplements in Expts 2.2 and 2.3 there was no significant difference in intake due to dental status. In contrast when concentrates were given in Expt 2.3 there was a tendency for the ewes with the inferior dental status (categories D + E) to consume more of the total amount available (12 and 25% for the 0·5 and 0.25 kg/DM/head allocations, respectively) than categories A + B.

Discussion

In the computation of an estimated hay intake for individual ewes, any associative effects between the dietary components on the digestibility of the total diet have been ignored. It is appreciated that the figures quoted for hay intakes may be only an approximation, but in all experiments the ratio of feedblock or concentrate intake to hay seldom exceeded 1 : 1 and was often much lower. At a similar ratio of concentrate to hay in the calibrating-digestibility trial, the digestibility of the hay increased by only 2·6 percentage units (from 51·6 to 54·2). Therefore even though the actual hay intake of some individuals may be underestimated, it is doubtful if the CV for hay intake would be markedly different from the values outlined. The results from Expt 2.4 when the hay intakes from individual sheep were also determined by weighing tended to be in close agreement with the estimated values which validates this assumption.

For groups of 16 sheep statistically significant differences in coefficients of variation for individual intake only occur when one variance is at least 2·4 x greater than the other. This criterion was only fulfilled for extreme differences in experimental conditions but it is not unreasonable to assume that large differences in variation in these experiments were indicative of biological significance.

In Expt 2.1 the greater individual variation for intake of both feedblocks exhibited by group B ewes was most likely due to the greater variation in dental status within the group. Upon completion of all the Expts, group B contained 44% ewes with dental category D or E (cf 19% in group A), consequently they were less well equipped to remove material from the intact feedblocks, especially the harder W291(74). It was noticed that the sheep with sound teeth removed block by a gauging action employing the central incisors. Ewes with these teeth absent were under a severe handicap and often resorted to the less rewarding process of licking, in terms of quantity of material consumed. As inspection of dental status only occurred at the start and upon completion of the experiments, any difference in rate of dental depreciation between the two groups, associated with the respective feedblocks given, could not be ascertained. The dental status of sheep is dynamic, in that for both young and mature individuals the status is imperceptibly but continually changing. The effect of prolonged block feeding on the extent and rate of dental depreciation is therefore worthy of further study, in view of the economic importance attached to a full compliment of teeth and reproductive life of the ewe.

In Expt 2.1 the variation in feedblock intake was always greater for the harder W291(74) block irrespective of group of ewes. This is consistent with the hypothesis that dental status was probably the principal determinate of the extent of individual variation in these experiments, the harder the feedblock given the more important dental status became to the individual.

Other factors possibly contributing to the greater variation on the harder W291(74) feedblock are palatability, absolute level of intake attained and pattern of feedblock consumption. The hardness of the feedblocks used was determined by the amount of calcium carbonate and/or hydroxide included, which reacts with the molasses in the block to form calcium sucrosate. Calcium sucrosate is a very bitter-tasting chemical and is present in the harder W291(74) block in a higher proportion than the softer W290(74) feedblock. It is possible that some ewes might have been dissuaded to consume the W291(74) block because of this greater unpalatable calcium sucrosate inclusion.

The higher absolute level of intake attained for the softer W290(74) feedblock might also have contributed to the lower CV. If it is assumed that the experimental error arising from faecal sampling, chromium determination and losses of faeces is likely to be in the same order for both blocks, such errors would contribute a greater proportion of the group mean for the harder W291(74) block and result in a higher CV for individual intake. When group A ewes were given the W291(74) block after the changeover in Expt 2.1 they consumed significantly more block than group B ewes. This difference in absolute level of block material consumed probably reflected differences in dental status between the two groups but the influence of a training effect could not be ruled out. Group A ewes might have been encouraged to spend more time at the block than group B ewes because of their previous history of consuming the softer W290(74).

In Expt 2.1, it was soon apparent that the total group intake of both feedblocks was markedly elevated over the initial 24-hr period of access to new blocks. As the level of intake on the softer W290(74) block necessitated daily introduction of a new block, any variation due to this 'first-day' effect was minimised. However for the harder W291(74) block the total group intake was on occasions three times greater on the day a new block was introduced than the overall mean intake. The cause of this elevated initial 24-hr intake could be due to the clean, dry nature of the block proving more palatable to the ewes but more likely the increase was mainly attributable to the fragile corner material of the rectangular block which was very easy to break off. This may have been exacerbated by the uptake of moisture during storage (The Wintawell (1974) feedblocks were packaged in cardboard containers which failed to eliminate moisture penetration). Therefore the pattern of this inter-day variation in total quantity of feedblock consumed by the sheep groups is another possible contributory factor to the magnitude of individual variation for the respective blocks.

The results of the behavioural study indicated that there was no discernable peak attendance period at the feedblocks and the distribution of visits and time spent at the blocks for these ewes was relatively uniform over a 24-hr period. The time of least activity was between 24.00 to 06.00 hrs when approximately 70% of the time was spent lying. Ewes given the harder W291(74) feedblock made fewer visits to the block, interrupted each visit earlier and consumed block material more slowly than their counter parts on the softer W290(74) block. There was a tendency for some ewes with an inferior dental status to visit the blocks less frequently than ewes with a full complement of incisor teeth. The minumum number of visits were 3 and 21/day for harder W291(74) and softer W290(74) respectively. Other sheep particularly on the W290(74) block made over 50 visits/day to the block. It is difficult to envisage an extensive situation where it would be possible for sheep to visit blocks at anything approaching the frequency of the indoor situation described here. However it is possible that frequency of block consumption may be advantageous in some circumstances especially where the utilisation of urea is concerned. Group B ewes consumed an estimated 11% more hay when given the harder intact W291(74) blocks (Expt 2.1) where frequent intake of urea occurred, than in Expt 2.2 when an equivalent amount of block was given once daily. This difference was not significant. This stimulated an investigation of the effect of giving urea once or frequently throughout a 24-hr period on the utilisation of cereal/straw diets for beef cattle (Expt 12.3).

In Expt 2.2, the comparison between giving equivalent quantities of the softer W290(74) in troughs (once daily) commensurate with the consumption from intact blocks (Expt 2.1) was confounded by the inability of the ewes to consume the material given in troughs without interrupting their feeding activity. The two treatments were therefore very similar in that the block material was on 'free-access' offer, albeit in a different physical form. The failure of sheep to consume large quantities of broken block rapidly, emphasises the unpalatable nature of the material and suggests that physical hardness per se is not wholly responsible for restricting intake of this particular block type. The urea inclusion in the block may be inhibiting the consumption of the ewes but much more likely is the bitter-tasting calcium sucrosate which also functions to impart block hardness.

The total quantity of the harder W291(74) block material given in troughs (Expt 2.2) was consumed rapidly without interruption and together with the results of giving concentrates in troughs (Expt 2.3), it appears for the ewes in these experiments, individual variation was greater when supplementary nutrients were given in a feedblock form (W291(74)) compared to giving equivalent amounts of DM in troughs. The trough space allowances were ample but not over generous, being consistent with those used in practice. The individual variation for ewes consuming a high intake of feedblock, (W290(74)), was of the same order, but no lower, than the variation arising from giving an equivalent allocation of DM as a concentrate in troughs.

The expression of feedblock intakes in terms of unit live weight in most cases slightly increased the amount of individual variation within a group. The converse occurred for the concentrate supplements, in that the heavier sheep consumed slightly greater amounts of the DM on offer. The differences in individual variation for the same ewes between the two levels of concentrate given were small.

The differences in individual variation for the low intake W291(74) feedblock and giving equivalent amounts of DM in troughs may have been influenced by factors inherent in the particular supplementation technique as well as biological variation inherent in the sheep such as dental status. Block feeding systems are characterised by the imprecise and variable total daily intake for any group of animals. It is the practice when giving concentrates to introduce a constant total allocation of DM for at least several days before carrying out a revision of the quantity given. No such control exerted by the stockfeeder exists for blocks, the animals per se determine the total quantity of material consumed daily in response to numerous environmental influences (Section 2).

In Expt 2.4 when the ewes were individually penned the previously large difference in level of intake between the two feedblocks disappeared, principally because of a considerable increased intake by group A ewes given the harder W291(74) block. Group B ewes also had a much higher intake of the softer W290(74) when the feedblocks were given individually, compared with the group situation in Expt 2.1. The reasons for the elimination of a significant difference in intake at a high overall level of consumption between the two blocks were most likely to be due to the increased surface area (particularly fragile corners) made available to the ewes in an individually penned situation. In Expt 2.1 a group of 16 ewes had access to the surface area and corners of one feedblock, in Expt 2.4 each of the groups of ewes was given the surface area and corners from 16 halved feedblocks, with a resulting provision of a greater quantity of easily consumed material.

When the ewes were individually penned it was hoped to eliminate the dominant-subordinate relationships in the group situation and identify any response by less dominant animals upon removal of this potential constraint of an increased feedblock intake. However, no such response seemed to exist, as both groups of ewes increased their individual block intakes, in most cases by a constant proportion over their intakes in Expt 2.1. Therefore, it appears that the influence of dominant-subordinate relationships on individual feedblock intakes were of lesser importance than factors such as the boredom, when animals are closely confined or more especially the quantity of easily consumed feedblock material from the higher ratio of feedblocks made available to the sheep.

The conditions under which the experiments described here were carried out are clearly not representative of the situations where most feedblocks are given to sheep, for several reasons. Most feedblocks given to sheep seem to be used in extensive hill situations, while in these experiments the sheep were always near the feedblcoks. The level of feedblock intake for even the harder W291(74) blocks failed to fulfil the main criterion of a supplement ($<5\%$ of the total diet, U.K. Fertiliser and Feedingstuff Act 1976) while in the hill situation a much lower level of intake probably would have occurred. The influences of the climate, herbage quality and quantity were also absent from these experiments. Therefore it is difficult to visualise circumstances where the individual variation in feedblock intake for mature ewes might be lower than recorded here. The individual variation of younger ewes possessing a full complement of incisor teeth is examined in Part B of this section.

B The individual variation in voluntary food intake within groups of ewes offered feedblocks or concentrates in competitive situations outdoors

The results of Part A of this section failed to support the claimed advantage that a more uniform type of supplementation will occur when nutrients are made available in feedblocks than is possible with the giving of concentrates in troughs. However, the experiments reported were conducted with mature ewes and it appeared that dental status was likely to be a major contributory factor to the individual intake of feedblock by any group of sheep. In Part B it was the intention to examine individual variation from feedblocks and compare this with equivalent amounts of concentrate DM as in Part A, but with younger ewes where dental status was relatively uniform, in that all individuals possessed a full compliment of strong incisor teeth.

The experiments also differed from those in Part A, in that they were carried out in an outdoor situation with the ewes in grass paddocks. It was hoped that the behaviour of the ewes would be representative of the majority of lowland sheep given feedblocks and sparse grazing and/or hay. It is possible that under the experimental conditions of Part A that a proportion of the individual intake variation for feedblocks might be attributable to over-consumption by some ewes because of boredom factors in the housed situation. In a field situation these may be less pronounced and the intake variation reduced accordingly.

In Part B several different types of feedblocks were examined which varied in chemical composition, philosophy of use, method of intake restriction, shape and recommended level of intake. The individual variation in feedblock intake was therefore examined at contrasting levels of consumption for blocks of differing palatability and acceptability.

A further objective of Part B was to examine the contribution to individual variation made by the irregular nature of feedblock consumption. This took the form of 'pair-feeding,' a second group of sheep with concentrates at an irregular input, imitating the consumption of feedblocks. Other measurements of intake variation were obtained when the same amount of concentrate was given at a fixed daily input.

Materials and Methods

The experiments were carried out in the autumn and winter of 1975/76. Thirty two pregnant Greyface (Border Leicester ♂ x Scottish Blackface ♀) ewes of mean live weight 66 kg (56 to 83 kg) were divided into two groups (C and D) on the basis of live weight. The ewes were purchased specially for these experiments and were approximately 3-years old with a full compliment of teeth. As far as was known the ewes had no previous history of feedblock consumption. Each group was given access to a small paddock (0·15 ha) which initially offered sparse grazing. The chemical composition and description of the feedblocks used in these experiments is given in Table 1 (page 35) of this thesis.

Experiment 3.1. A comparison between ewes given Rumevite feedblocks and concentrates given in troughs

In Expt 3.1 of 34 days duration group C ewes were given a RS feedblock in a purpose-built metal container which protected the sides and edges of the block. The container was provided with holes at the base to allow rain water to drain away but often these became blocked and the base of the blocks became soft. The feedblocks were weighed daily and replaced when less than 4 kg of fresh material remained. Chromic oxide was included in the blocks at 3·65 g/kg DM.

Group D ewes were given an allocation (66 g DM/head) of concentrate cubes (248 g CP, 32 g CF, 15 g EE and 87 g ash/kg DM) commensurate with the total DM intake of RS by group C ewes over the previous 24-hr period, thus mimicking the irregular DM intake of feedblock. Chromic oxide was included in the concentrate cube at 5·45 g/kg DM. The concentrates were given in troughs with a generous space allowance of 83 cm/ewe.

Both groups of ewes also received ad libitum timothy hay (81 g CP, 295 g CF, 16 g EE and 58 g ash/kg DM) in V-shaped metal feeders. The hay was usually introduced twice daily or when necessary and the amount given recorded.

The ewes were equipped with faecal collection harnesses and nylon mesh bags and a 6-day quantitative collection of faeces was made over days 12 to 17 after introduction of the blocks. Faeces were sampled according to Method (1) (page 71). The RS feedblock was then removed and a RHE feedblock substituted. The experimental procedure was not changed except that the concentrates were now allocated at a fixed daily input commensurate with the mean quantity of concentrate DM given before. A 6-day quantitative collection of faeces was made 12 to 17 days after introduction of the RHE feedblocks and changing the pattern of concentrate administration. Thus the effect on individual variation of giving concentrates at a fixed or irregular daily input could be made and compared with the individual variation arising from feedblock supplementation. The ewes were weighed upon completion of the experiment.

<u>Experiment 3.2. A comparison between ewes given Colborn feedblocks and concentrates in troughs</u>

In Expt 3.2 of 34 days duration an essentially similar experimental procedure for Expt 3.1 was employed. Group C ewes were given a CSE feedblock in a heavy-duty plastic container, which allowed access to only the top surface of the block. The CSE feedblocks contained 9·69 g chromic oxide/kg DM. Group D ewes received over the initial 17 days an allocation of concentrate cubes 'pair-fed,' on a daily DM basis, commensurate with the total intake of CSE by group C ewes. Over the second 17-day period of Expt 3.2 the concentrates were allocated as in

Expt 3.1 on a fixed daily DM basis (394 g DM/head). Faeces were quantitatively collected from both groups of ewes over days 12 to 17 and 29 to 34 to give 6-day composite samples.

Experiment 3.3. The measurement of individual intake variation for ewes given Wintawell feedblocks

In Expt 3.3 of 34 days duration, group C and D ewes were given W291(74) and W290(74) feedblocks, respectively, over the initial 17 days of the experiment. Over the subsequent 17-day period the feedblocks given to groups C and D, respectively, were W291(76) and W290(76). Chromic oxide was included in the feedblocks (2·40 g, 2·39 g, 4·51 and 8·21 g/kg DM for the W291(74), W290(74), W291(76) and W290(76) blocks respectively). No containers were used with any of the blocks in this experiment as this was the recommendation of the manufacturers.

The experimental procedure employed was identical with the previous Expts (3.1 and 3.2) with 6-day quantitative faecal collections made over days 12 to 17 and 29 to 34 from both groups of ewes.

Computation of data

The individual intakes of feedblocks and concentrate were estimated from the recovery of chromic oxide during the respective sampling periods. The DM digestibility of the Colborn (CSE) and Wintawell (W290(74), W291(74), W290(76), W291(76)) feedblocks used was assumed to be equivalent to the values given in Table 7, the DM digestibility of the concentrates was 83·0% and the DM digestibility of the hay was 54·8%. No DM digestibility estimates could be given for the Rumevite feedblocks for the reasons outlined on page 74.

In Expts 3.2 and 3.3 the individual hay intakes of the ewes were estimated by apportioning faeces according to the indigestibility of the dietary components. The total DM intake of individual sheep was also calculated.

The individual variation in intakes of feedblock, concentrate and hay and total DM (Expts 3.2 and 3.3) were computed both in absolute quantities and expressed per unit live weight. For the sake of brevity only results expressed in absolute terms are presented here but comment will be made on the data when expressed on a unit live-weight basis. For the same reasons individual intakes will not be given apart from Expt 3.1.

Results

In Expt 3.1 the mean daily DM intakes of the RS and RHE feedblocks by weighing were 65 ± 7·7 and 66 ± 15·0 g, respectively, over the experimental period. Group C ewes given RS consumed 41% more hay DM than the 'pair-fed,' concentrate ewes (group D), the difference (1113 ± 82 v. 790 ± 192 g) was not significant. When group C ewes were given the RHE feedblock their intake of hay DM (1343 ± 26 g) was significantly greater ($P < 0{\cdot}05$) than group D ewes given concentrates (828 ± 221 g). The intakes of feedblock did not appear to increase with time. The individual feedblock and concentrate intakes for Expt 3.1 are presented graphically in Fig. 3.

The CVs for individual concentrate intake both for an irregular (46%) and a regular (48%) concentrate inputs were below that for the feedblocks (CV equivalent to 64 and 70% for the RS and RHE feedblocks respectively). One individual ewe failed to consume any RHE and only 10 g/day of RS, the CV was reduced to 59% for the RHE feedblock when this ewe was not included in the analysis.

The mean intakes of feedblock, concentrate, hay and total dry matter for Expts 3.2 and 3.3 are given in Table 13, together with respective coefficients of individual variation. In Expt 3.2 the mean daily intake of CSE over the whole experimental period was 418 ± 28·3 g DM/head and a new block had to be introduced on alternate days. When both the CSE feedblock and the concentrate allocation were consumed on

Fig.3 Expt 3.1 The individual variation in the intake of feedblocks RS and RHE and equivalent weights of concentrate DM allocated on either (a) 'pair-fed' or on an irregular daily intake basis or (b) given uniformly each day.

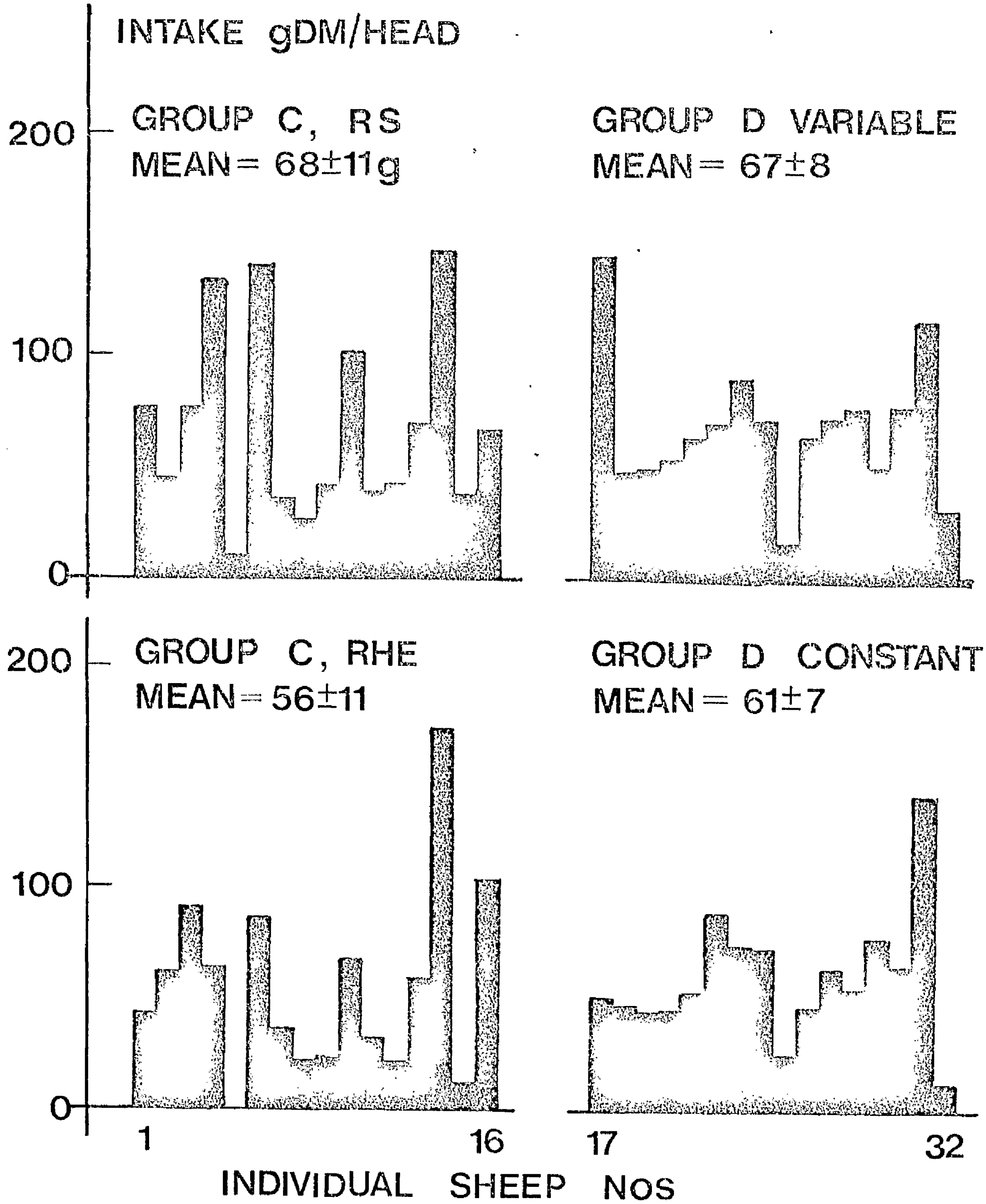

INTAKE gDM/HEAD
GROUP C, RS
MEAN = 68±11g
GROUP D VARIABLE
MEAN = 67±8
GROUP C, RHE
MEAN = 56±11
GROUP D CONSTANT
MEAN = 61±7
200
100
0
200
100
0
1
16
17
32
INDIVIDUAL SHEEP NOS

Table 13. Expts 3.2 and 3.3. Mean intakes (16 sheep) of feedblock, concentrate, hay and total DM and their respective coefficients of variation

	Expt 3.2				Expt 3.3			
	CSE (Group C)		Concentrates (Group D)		W291 (Group C)		W290 (Group D)	
DM intake g	Days 12-17	Days 29-34	Irregular daily basis Days 12-17	Regular daily basis Days 29-34	(74) Days 12-17	(76) Days 29-34	(74) Days 12-17	(76) Days 29-34
a) Feedblock or concentrate	336	392	336	358	181	178	410	474
	(53.4)+	(59.7)	(55.2)	(31.0)	(80.7)	(95.6)	(46.8)	(76.1)
b) hay	1211	1252	1166	1186	1297	1349	1233	1177
	(21.4)	(18.3)	(18.2)	(17.6)	(17.8)	(10.1)	(19.3)	(17.7)
c) Total	1547	1644	1502	1544	1478	1527	1643	1651
	(22.9)	(17.1)	(20.3)	(14.9)	(20.6)	(20.6)	(18.5)	(18.1)

+ CV%

an irregular basis (days 1 to17) there was no difference in intake variation (CV 53 v. 55%) for the two methods of giving nutrients. However when the concentrates were given to group D ewes at a constant allocation/day (mean intake 358 g) the CV was considerably reduced (31%). There was only a small difference in CV (53 v. 60%) between the successive collection periods when individual variation of the CSE feedblock was measured. The individual ewe in group C which refused to consume RHE also refused to consume the CSE feedblock. When this ewe was eliminated from the data the respective CVs(45 and 52%) for collection periods (days 12 to 17 and 29 to 34) were reduced. The expression of intakes of the CSE feedblock and concentrate (collection 29 to 34 days) per units live weight did not alter the CV for individual intake and only a small decrease was recorded (CV reduced from 55 to 49%)in the concentrate variation for the 12 to 17 day collection.

In Expt 3.3 the intakes over the total experimental period of W291(74), W291(76) (group C ewes) and W290(74), W290(76) (group D ewes) were 175 ± 21, 188 ± 14, 441 ± 28 and 408 ± 33 g, respectively. The pronounced 'first-day' effect resulting in an increased consumption over the initial 24-hr period for the housed ewes (Part A) given Wintawell (1974) feedblocks was much less evident with the present ewes outdoors. The individual variation in feedblock intake was especially large for the harder W291(74) and W291(76) feedblocks (81 and 96%, respectively). The absolute level of intake was the same for these blocks. The intake variation (CV = 47%) for the W290(74) block was relatively small and a considerable improvement on the 76% measured for W290(76). The mean intake from both blocks was approximately similar. The same individual ewe in group C also refused to consume any of the feedblocks given in Expt 3.3 and a second ewe in group C consumed none of the W291(76) block. When these sheep were eliminated from the data the CVs for W291(74) and W291(76) were reduced to 74 and 83% respectively. The expression of intake variation in units of live weight did not fundamentally alter the CVs obtained.

In Expts 3.2 and 3.3 the CV for hay and total DM intake were in all cases considerably below those calculated for either the feedblocks or concentrates. In the extreme case of group D ewes given the W290(74) feedblock the CV for hay intake (10%) was about 10 times below the value for block intake (96%).

Discussion

In Expts 3.2 and 3.3 when individual hay intakes were estimated by apportioning faeces according to the indigestibility of the feedblock, concentrate or the hay dietary component, no attempt was made to calibrate any likely associative effect between the components, resulting in a change in total digestibility of the diet. Also the contribution from the grazing available in the paddocks was ignored. This seemed a valid assumption because on completion of Expt 3.1 the paddocks were very bare and the ewes apparently relied almost totally on the hay given, to supply roughage. Therefore the hay and total DM intakes given are approximations but serve to show the much reduced individual variation for the roughage component of the diet, compared with either giving feedblocks or concentrates.

In all the experiments carried out here the individual variation for feedblocks was greater than for giving equivalent amounts of DM as concentrate cubes in troughs, with one exception. In Expt 3.2 when the concentrates were allocated on an irregular basis the CV for individual intake was similar to that for the concentrates. This agrees with the indoor findings in Expts 2.1, 2.2 and 2.3 where a more uniform supplementation with feedblocks over 'hand-feeding' was not recorded, which is contrary to the situation commonly imagined. Perhaps the most interesting outcome of the outdoor experiments was that even when a small amount ($< 5\%$ of the total DM intake) of feedblock was consumed (mean 50 to 60 g/day) such as occurred in Expt 3.1 from RS and RHE, the ewes given an equivalent amount of DM as a concentrate in troughs still showed less individual variation than the feedblock supplemented ewes. Therefore even in the true supplementation situation, with these ewes the 'self-feeding,' of sheep with feedblocks did not produce a more uniform intake than 'hand-feeding.' This is rather surprising because the concentrate allocation was literally consumed in seconds and the ewes showed considerable disturbance at the troughs. Also unlike the indoor experiments in part A, all the ewes employed in the present experiments possessed a good dental status and in theory should have been able to consume block material if sufficiently motivated.

The ranking of the sheep according to their feedblock or concentrate intakes within their respective groups remained remarkably constant regardless of feedblock type or level of concentrate given. One individual ewe completely refused to consume any of the feedblocks given apart from a token intake (10 g/day) on the RS which was the initial block provided for her group. This may have been a novelty interest only. When the ewes were subsequently housed in late winter for lambing it was observed that this ewe readily consumed concentrates in a competitive situation. A second individual appeared to suddenly stop consuming feedblocks when given the W291(74); the reason for this could not be explained for the ewe seemed in perfect health and readily consumed hay. All ewes competed at the troughs for the concentrates given but in some instances, particularly in Expt 3.1, low individual intakes were recorded.

The influence of giving the concentrates on an irregular input basis on the magnitude of individual intake variation in Expts 3.1 and 3.2 seemed to depend on the level of concentrate allocated. When a small allocation (66 g DM/head) was given (Expt 3.1) there was little difference in individual variations regardless of method of concentrate allocation. When a larger amount of concentrate (394 g DM/head) was given (Expt 3.2), the individual variation in concentrate intake was considerably reduced if the concentrates were allocated at a constant daily input (practical method of giving concentrates), than for a variable daily input (256 to 513 g DM/head). Therefore at a supplemental level of intake (< 5% of total DM intake in Expt 3.1) for both feedblocks and concentrates it is doubtful whether the inter-day variation in total quantity of DM on offer contributed materially to the magnitude of individual intake variation. As the proportion of feedblock or concentrate in the diet increased to 20 to 25% and individual intake variation was reduced (Expt 3.2), the inter-day variation in total concentrate or feedblock DM given, appeared to influence considerably the magnitude of individual intake variation, by increasing it. At the low level of concentrate allocation, consumption was extremely rapid and it is likely that individual ewes were consuming concentrate in proportion to the total amount on offer, thus the intake variation was independent of the method of daily allocation of concentrates.

When the amount of concentrate given was increased to 20 to 25% of the total DM intake, the consumption time increased accordingly to several minutes. When the concentrates were now allocated at a constant daily input the motivation and competitive ability of individual ewes probably rewarded them with a relatively constant amount of concentrate DM/day. However when the concentrates were allocated at an irregular input it is possible that the motivation of some ewes waned when a large amount of DM was given and they interrupted feeding before the more greedy individuals. Similarly, on days when the allocation of concentrate was much reduced the motivation of the greedy ewes increased and they increased intakes accordingly i.e. individual daily concentrate intakes were no longer in proportion to the total amount of DM given.

The factors which affect inter-day variation in feedblock intakes, for instance weather, are examined in the next section of this thesis. It is likely that a similar situation exists for feedblocks as with the irregular allocation of concentrates in these experiments. With the low intake supplement-type feedblocks, it is unlikely that inter-day variation in total group intake will profoundly affect the extent of individual intake variation because of other 'masking' causes, such as block hardness and unpalatability of ingredients. With the more palatable substitute-type feedblocks the inter-day variation in total group intake may be a significant contributory cause to individual intake variation. The intake of substitute-type feedblock between days by individual ewes appears to be no longer in proportion with inter-day total group intake.

Therefore an extra source of individual intake variation exists which is peculiar to feedblocks and 'self-fed' systems in general. Even when the more palatable substitute-type feedblocks such as CSE, W290(74) and W290(76) are given to sheep with uniform dental status, the individual variation is greater than for concentrates given at a constant daily input. Therefore the claimed advantage of feedblocks over trough given nutrients, that a more uniform supplementation will be effected appears to be unfounded. The amount of trough space per ewe for the concentrate diets was generous (83 cm) and it is possible and indeed likely that individual variation in concentrate intake would increase as trough space became limiting. This aspect was examined in Part C of Section 1.

C The effect of trough space allowance on the individual variation in concentrate consumption and a comparison with the giving of nutrients in feedblocks and cobs for ewes in competitive situations outdoors

The results of Parts A and B of this section demonstrated that if sheep are given an adequate allowance of trough space, a more uniform consumption of the DM available by individuals in the group is likely to occur for concentrate foods than is possible with 'self-help' feedblocks. However, when trough space is limiting, an increase in individual intake variation may occur and it was one of the intentions of Part C to examine individual variation at various trough space allowances and DM allocations of concentrates. Several feedblock types representing different block shapes, methods of intake control and philosophy of use were also given as in Part B, to effect a comparison between 'hand-feeding' of concentrates and 'self-feeding,' using blocks. A comparison between the giving of cobs and concentrates or feedblocks was also made.

Materials and Methods

The experiments were carried out in the autumn and winter of 1976/77. A group of 36 Greyface ewes was allowed access to a permanent grass paddock of approximately 4 ha. All the ewes possessed a full compliment of permanent incisor teeth and were 3 or 4-years of age. Over the initial 4 weeks of the experiments 2 rams were running with the ewes. The ewes had previous experience of consuming concentrates from troughs and feedblocks but not cobs. The quantity of grazing afforded by the paddock was considered sufficient roughage for the ewes from September 1976 until the beginning of January 1977 when adequate hay was made available in racks.

Experiment 4.1. The effect of trough space allowance and quantity of concentrate DM allocated on the individual intake variation of concentrates given in troughs

A concentrate cube of similar composition to that used in Expts3.1 and 3.2 was made, incorporating 5·54 g chromic oxide/kg DM. The ewes were given the following daily allocations of concentrate, progressively over 3 consecutive 24-day periods, 84, 252 and 504 g/head. The 24-day periods were subdivided into three 8-day periods when each allocation of concentrates was given at 3 different trough space allowances. These were 53 cm/head (4 troughs), 40 cm/head (3 troughs) and 33 cm/head ($2\frac{1}{2}$ troughs). The troughs measured 2·4 x 0·25 m and in calculating the trough space allowances given, measurements of both sides of each trough have been included. Metal struts partitioned off each trough into 8 compartments and it is recognised practice to allow 12 sheep/trough of this type. Therefore 4 troughs gave a generous space allowance, 3 troughs average and $2\frac{1}{2}$ troughs gave a tight space allowance.

Unlike the experiments carried out in Parts A and B of this section, when total faecal collections were made from the ewes, in these experiments resources only permitted the use of rectal grab samples to estimate the individual intakes of the foods given. On day 8 of each sub-period (following 7 days of intorudction to each permutation of concentrate allocation and space allowance) the ewes were penned and rectal grab samples obtained.

Experiment 4.2. The individual variation of ewes given feedblocks or cobs using rectal grab samples to estimate individual intakes

The experimental procedure was very similar and directly consecutive to Expt 4.1. The following feedblocks were given to the 36 ewes over consecutive 12-day periods, RS, RHE, W290(76), W290(74), W291(74) and CSE (Table 1 for typical feedblock compositions). The feedblocks contained 4·40, 5·18, 8·21, 2·39, 2·40 and 9·69 g chromic oxide/kg DM respectively. On day 12 of each period the ewes were penned and rectal grab samples obtained from as many ewes as possible. No containers were used for the feedblocks. Two blocks of each respective type were given to the ewes and replenished when less than the previous days consumption of block remained. Any residues were removed if necessary.

About 16 days before the onset of lambing 2 ewes were removed from the experiment due to weakness. The remaining 34 ewes were then given 640 g DM/head/day of cobs (141 g CP, 39 g CF, 20 g EE, 125 g ash, 2·16 g chromic oxide/kg DM) for a 7-day period, after which they were rectally grab sampled. Each cob measured 4 x 4 x 1·7 cm and weighed a mean 25 $\pm$ 0·7 g DM. During the week preceeding the expected lambing date the ewes were given 960 g DM/head/day of similar cobs. The sheep were again grab sampled and housed for lambing. When the cobs were given they were spread out over a large area of clean ground each day.

Results

Experiment 4.1

The concentrates were totally consumed in about 3, 5 and 10 minutes for the 84 g, 252 g and 504 g DM allocations, respectively. All the sheep came to the troughs irrespective of the quantity allocated or trough space allowance, although at the lowest concentrate allowance given with the tightest trough space, several individuals quickly stopped competing.

The mean, range and coefficient of variation for faecal chromic oxide concentrations at the various trough space allowances and allocations of concentrates during Expt 4.1 are given in Table 14.

The lowest CV for faecal chromic oxide concentration (26·8%) was obtained when 504 g concentrate DM/head was given at a trough space allowance of 53 cm/head (the largest allocation of concentrate given at the most generous trough space allowance). The highest CV for faecal

Table 14. Expt 4.1. Mean, (36 sheep) Range (g chromic oxide/100 kg DM) and coefficient of variation for faecal chromic oxide concentrations at 3 different levels of concentrate allocation and trough space allowances

Trough space cm/head	53			40			33			Overall mean		
Concentrate g DM/head	Mean	Range	CV%	Mean	Range	CV%	Mean	Range	CV%	Mean	Range	CV%
84	120	37-280	45.9	95	14-332	57.8	69	6-365	73.6	95	27-199	42.4
252	388	200-690	36.7	239	77-459	37.2	391	156-707	42.9	339	165-615	34.1
504	710	459-1140	26.8	981	251-1991	37.9	852	447-1414	34.3	848	324-1393	29.4
Overall mean	406	209-622	32.3	438	168-807	35.0	437	193-677	38.7	427	-	35.3

chromic oxide concentration (73·6%) occurred when the lowest allocation of concentrate (84 g DM/head) was given at the tightest trough space allowance (33 cm/head).

There was a tendancy for the CV for faecal chromic oxide concentration to decrease, as amount of concentrate given increased at all trough space allowances. When the 3 grab samples for individual sheep at each trough space allowance were combined together, the resulting CV for faecal chromic oxide concentrations were 42·4, 34·1 and 29·4% for the 84, 252 and 504 g DM/head allocations of concentrate, respectively.

The individual faecal chromic oxide concentrations (mean of the 3 samples), when 84 g concentrate DM/head was given, were significantly ($P < 0·01$) correlated ($r = 0·44$ and $r = 0·48$ respectively) with the faecal chromic oxide concentrations for individual sheep, when either 252 or 504 g concentrate DM/head was given. The individual faecal chromic oxide concentrations when 252 g concentrate DM/head was given were also significantly ($P < 0·01$) correlated ($r = 0·50$) with those when 504 g concentrate DM/head was given.

There was also a tendency for the CV for faecal chromic oxide concentration to increase as trough space allowance decreased, which was most apparent at the lower levels of concentrate allocation (84 and 252 g DM/head). When 504 g DM/head of concentrate was allocated there was little difference in the CV for faecal chromic oxide concentration at either the 40 or 33 cm/head trough space allowances (37·9 and 34·3% respectively), although both were greater than the 53 cm/head allowance (CV = 26·8%). When the 3 grab samples for individual sheep at each level of concentrate allocation were combined together, the resulting CV for faecal chromic oxide concentrations were 32·3, 35·0 and 38·7% for the 53, 40 and 33 cm/head trough space allowances, respectively.

The individual faecal chromic oxide concentrations (mean of 3 samples) when the concentrate allocations were given at a trough space allowance of 53 cm/head were significantly ($P < 0 \cdot 001$) correlated ($r = 0 \cdot 61$ and $0 \cdot 58$) with those at trough sapce allowances of 40 and 33 cm/head, respectively. The individual faecal chromic oxide concentrations when the ewes were given the concentrate allocations (mean of 3 samples) at a trough space allowance of 40 cm/head were significantly ($P < 0 \cdot 01$) correlated ($r = 0 \cdot 54$) with the chromic oxide concentrations at the 33 cm/head space allowance.

Experiment 4.2

All the ewes given feedblocks or cobs appeared to have chromic oxide in the faeces, albeit only a small amount in several instances. The mean daily DM intake (Table 15) of the RS feedblock was 69 ± 9 g/head which was significantly ($P < 0.01$) below the intake of RHE (102 ± 7 g/head). The mean daily intakes of the W290(74), W290(76) and CSE feedblocks were 407 ± 23, 457 ± 22 and 462 ± 13 g DM/head, respectively, all approximately of the same order. For these substitute-type feedblocks the level of intake attained by the 36 ewes required a new feedblocks to be introduced daily. The mean daily intake of the W291(74) feedblock (304 ± 50 g DM/head) was intermediate in level, being above that of the supplement-type feedblocks but below the substitute-type blocks.

The mean, range and CV for faecal chromic oxide concentrations for the various feedblocks or allocations of cobs are also given in Table 15.

There was little difference in CV for faecal chromic oxide concentration for the RHE, W290(74) and W290(76) feedblocks (53·7, 53·0 and 54·4% respectively). The CV for the RS and W291(74) feedblocks were also approximately similar (61·1 and 63·2%, respectively) though higher than for the RHE, W290(74) and W290(76) feedblocks. The lowest CV for faecal chromic oxide concentration (34·8%) was obtained with the CSE feedblock. The CVs for faecal chromic oxide concentration

Table 15. Expt 4.2. Mean daily intakes of feedblocks or cobs and mean, range and coefficient of variation for faecal chromic oxide concentrations (g/100 kg faecal DM)

Feed blocks given	Mean daily intake g DM/head	Faecal chromic oxide concentrations g/100 kg DM		
		Mean	Range	CV%
RS	69 ± 9	108 (32)+	31 - 251	61.1
RHE	102 ± 7	240 (33)	33 - 358	53.7
W291(74)	304 ± 50	72 (31)	14 - 202	63.2
W290(74)	407 ± 23	183 (33)	50 - 542	53.0
W290(76)	457 ± 22	528 (33)	91 - 1013	54.4
CSE	462 ± 13	426 (27)	121 - 686	34.8
Cobs	640	178 (27)	54 - 277	29.5
Cobs	960	251 (24)	143 - 406	27.1

+ Number of faecal samples analysed (Mean 36 for blocks, 34 for cobs).

(29·5 and 27·1% respectively) when the sheep were given either 640 or 960 g DM/head from cobs, were lower and consequently intake was apparently more uniform, than when any of the feedblocks were given.

The individual faecal chromic oxide concentrations when the sheep received the RS and RHE feedblocks were very closely correlated (r = 0.84), which was significant at P< 0·001. The faecal chromic concentrations when the sheep were given W290(76) were not significantly correlated with the chromic oxide concentrations when the sheep received either W290(74), W291(74) or CSE. The faecal chromic oxide concentrations for the W290(74) feedblock were significantly (P< 0·001) correlated (r = 0·81 and 0·66) with the concentrations when the sheep received W291(74) and CSE, respectively. The faecal chromic oxide concentration for the W291(74) feedblock was significantly (P< 0·01) correlated (r = 0·52) with the concentrations for the CSE feedblock.

When the two samples for the Rumevite type feedblocks (RS and RHE) were combined together, the resulting faecal chromic oxide concentrations were significantly (P< 0·001 and P< 0·01) correlated (r = 0·80 and 0·69) with the concentrations for the W291(74) feedblock and the mean chromic oxide concentration for the substitute-type feedblocks combined (W290(76), W290(74) and CSE , respectively). The correlation (r = 0·69) between faecal chromic concentrations for the W291(74) and substitute-type feedblocks combined was also significant at P< 0·001.

The correlation (r = 0·61) between the faecal chromic oxide concentrations when the sheep received either 640 or 960 g DM/head of cobs was significant at P< 0·01.

Discussion

Expts 4.1 and 4.2 consisted of 17 different permutations of giving extra nutrients to the same group of ewes. This enabled a comparative assessment of individual variation in intake (faecal chromic oxide concentrations) for 'hand-feeding' (9 different combinations of concentrate and trough space allowance and 2 allocations of cobs) to be made with 'self-feeding', when the ewes were given 6 different feedblocks, embracing several manufacturing techniques and philosophies of use. The results of both experiments have been summarised in Fig.4 which shows the relationship between the mean quantity of DM consumed for the various methods of giving additional nutrients and the coefficient of variation for individual intake. As the concentrates (different levels of allocations and trough space allowances), individual feedblocks and cobs were only given for short periods of time, any 'training' or 'adaptation' to the particular system of giving nutrients was probably not allowed to occur. There may also have been some carry-over effects from the previous treatments. However the lowland ewes employed in Expts 4.1 and 4.2 were well used to receiving additional nutrients in concentrates or feedblocks and the individual variation in intake would almost certainly be greater for some or all of the permutations if less experienced ewes had been used.

In general the results tended to agree with those of Parts A and B of this Section, that the giving of nutrients as concentrates in troughs results in a more uniform type of individual intake, than when similar quantities of DM are taken from feedblocks. Only on one occasion was the CV for feedblock intake less than 50% (CSE, CV = 35%). Conversely, only for 2 of the 9 combinations of concentrate and trough space allowance was the CV greater than 50% (i.e. with the smallest, 84 g DM/head allowance of concentrates, given at the most restricted trough space allowances of 40 and 33 cm/head). There was little difference in individual variation when cobs were given, compared to approximately similar quantities of concentrate, given at a generous trough space allowance (53 cm/head).

There was a tendency for individual variation in intake to decrease inversely with increasing amount of DM, particularly when 'hand-feeding' was practised. This trend was probably not completely due to biological reasons but may also reflect a reduction in the error

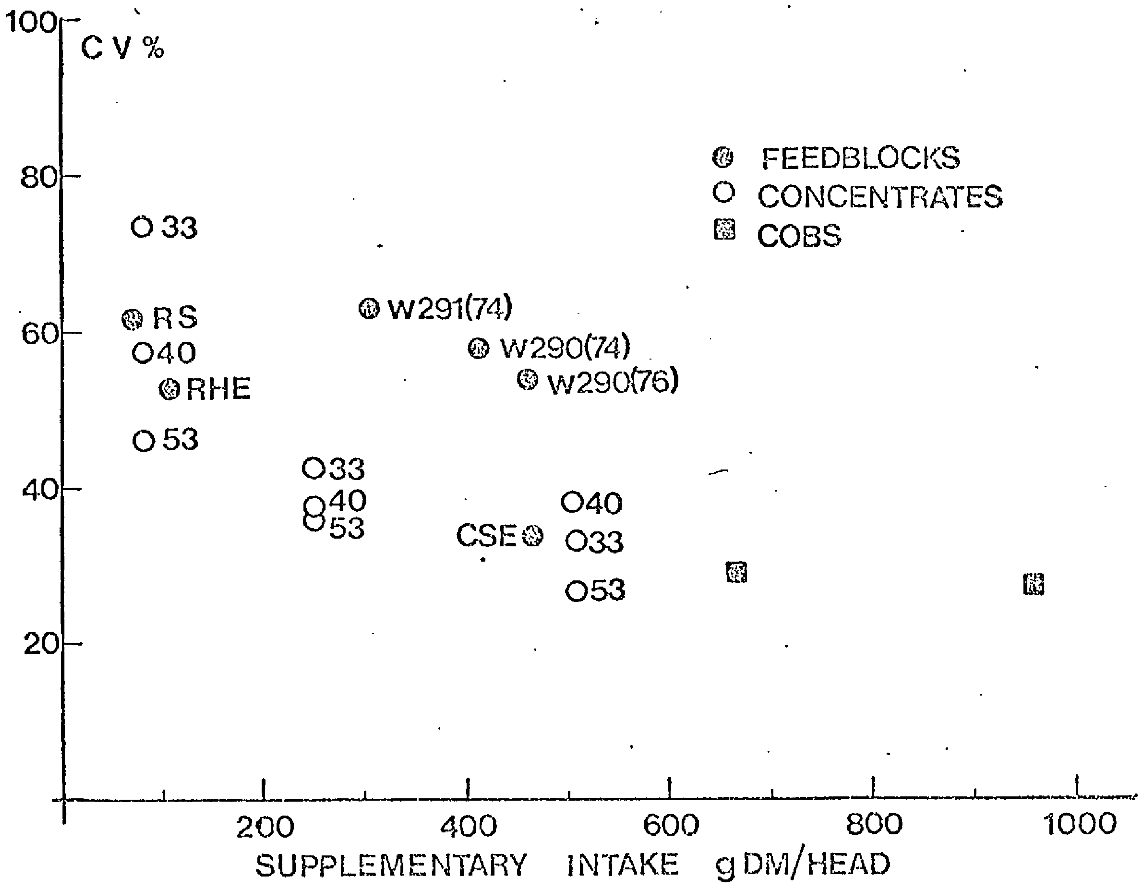


Fig.4 Expts 4.1 and 4.2 The relationship between CV for faecal chromic oxide concentrations and the mean quantity of DM consumed (g/head/day) as either (a) feedblocks (b) concentrates at trough spacings of 33, 40 and 53 cm/head and (c) cobs.

variation inherent in the experimental technique. For example, as the intake of nutrients containing chromic oxide increase, chromic oxide content of the faeces increases in proportion and any analytical error is diluted by the larger amount of chromic oxide in the faeces.

Also the inclusion rates of chromic oxide in the feedblocks but not the 'hand-fed' supplements varied (2·39 to 9·69 g chromic oxide/kg). Thus the supplement-type (Rumevite) feedblocks allowed a lower intake of DM combined with a lower inclusion of chromic oxide compared to, for example, the CSE feedblock. If possible it would be an advantage to have chromic oxide inclusion rates standardised for the different feedblock types. Nevertheless, the greatest proportion of this decrease in individual variation with increasing intake must be attributable to biological causes and reflect a real improvement in uniformity of supplementation. The reasons for this improvement must be intimately concerned with the behaviour of the ewes. It was noticeable that when only a small amount of concentrate (84 g DM/head) was given (especially on a 'tight' trough space allowance) the inclination of some ewes to compete, quickly waned and they walked away from the troughs and recommenced grazing. However, when larger quantities of concentrate were given (252 and 504 g DM/head) the 'interest,' of all the sheep in the food was maintained for a much longer period until virtually all the concentrate had been consumed. Therefore, at the lowest concentrate allocation the 'greedy' (more competitive) ewes consumed a disproportionately large amount of the total quantity given,whilst the less competitive sheep consumed only small quantities, the net effect resulted in increased individual intake variation than when larger quantities of concentrate were given.

In practice, it is seldom that a quantity of DM as low as 84 g/ head (3 ozs/head) is given to sheep as a concentrate and therefore although a useful comparison with the feedblocks supplying equivalent

DM it is somewhat artificial in other respects.

As expected, individual variation in concentrate intake became greater as trough space became limiting. At the lowest (84 g DM/head) allocation of concentrate the individual variation at generous (53 cm/head) space allowance was superior to the supplement-type feedblocks. At average (40 cm/head) space allowance there was little difference and at restricted space allowance (33 cm/head) the individual variation for the supplement-type feedblocks was less than for concentrates.

At the 252 g DM/head concentrate allocation there was less difference in individual variation for the various space allowances but the ranking for magnitude of individual variation still varied proportionally with space allowance. The individual intake variation was much superior to the W291(74) feedblock which supplied approximately the same mean DM intake (252 and 304 g/head for concentrate and block, respectively).

The importance of trough space allowance appeared to be considerably less when the highest allocation of concentrate (504 g DM/head) was given. The generous space allowance (53 cm/head) gave the most uniform type of intake but the restricted and average trough allowances (33 and 40 cm/head respectively) showed little difference in precision of intake (the restricted was in fact slightly superior to the average allowance). Only the CSE feedblock of the 3 substitute-type blocks allowed a uniformity in intake of the same order, as when an approximately similar quantity of DM was consumed from troughs (462 and 504 g DM/head, respectively). Even then the generous space allowance was superior in terms of uniformity to the (CSE) block.

The 'hand-feeding' of additional nutrients as cobs was also superior to the 'self-feeding' of approximately similar quantities of DM as feedblocks (W290(76), W290(74) and CSE).

One of the objectives of Expts 4.1 and 4.2 was to discover if the ranking of individual DM intakes when 'hand-feeding' was practised was in the same order, as when similar total quantities of DM were consumed by the same group of sheep from feedblocks. As it was shown that the individual intakes (faecal chromic oxide concentrations) of the supplement-type (RS and RHE) feedblocks were closely correlated the two samples were combined. Likewise because the W290(76), W290(74) and CSE feedblocks gave mean intakes approximately similar in magnitude and the individual intakes for the latter two blocks were closely correlated, the faecal chromic oxide concentrations were combined.

There were no significant correlations between the individual intakes (mean of 2 samples) of the supplement-type feedblocks (RS and RHE) and when an approximately equivalent amount of DM (84 g/head) was given as concentrates in troughs (mean of 3 samples). There were also no significant correlations between the individual intakes (faecal chromic oxide concentrations) for the W291(74) feedblock and the intermediate amount of concentrate (252 g DM/head) given in troughs. The correlation between the individual intakes of the substitute-type feedblocks and when 504 g DM/head was allocated in troughs (both mean of 3 samples) was also not significant. However the individual intakes when 640 g DM/head was given as cobs was significantly ($P < 0{\cdot}01$) correlated ($r = 0{\cdot}54$) with the intakes when the 504 g DM/head allocation of concentrate was 'hand-fed.'

Therefore the factors which determine the ranking of individual intakes in a group of sheep when 'hand-feeding' (concentrates or cobs) is practised are completely different from the factors which influence the ranking when 'self-feeding' is practised. This is in agreement with Expt 2.1. When dental status was shown to be a very important factor in determining the individual intake of feedblocks but of little consequence for 'hand-fed' foods.

The results of the experiments described here again failed to substantiate the claim that because 'self-fed' foods such as feedblocks are constantly available to the animals they allow a more uniform type of intake to be effected than 'hand-fed' nutrients. It was only when a very small amount of concentrate DN was given and trough space became severely limiting that feedblocks gave a more precise type of supplementation than concentrates given in troughs. As stated earlier it is rarely desired to give such a small amount of concentrate in practice and only when management is particularly bad would the restriction on trough space be as severe as the 'tightest' allowance used here. Of all the feedblocks used the CSE appeared to be the most likely to give a relatively uniform intake on par with 'hand feeding.' This is in agreement with Part B, Expt 3.2 of this Section when CSE feedblocks also gave more uniform intakes than the other feedblocks studied.

D The individual variation in feedblock intake for groups of sheep containing mature and 2-year old ewes (gimmers) outdoors in late pregnancy

A claimed advantage for the use of feedblocks is that they encourage 'shy-feeders,' particularly 2-year old ewes (gimmers) to consume supplementary nutrients. Traditionally a 'shy-feeder' is an animal which refuses to compete for nutrients given in troughs and as a result may seriously lose body condition. Hill breeds of sheep such as the Scottish Blackface, Swaledale and Welsh Mountain are notorious for their reluctance to consume supplementary feeds. Even in cross-bred flocks, the gimmers are sometimes slow to make use of trough-given supplements and the nutritional penalty imposed on the still growing sheep in late pregnancy can be severe.

Several experiments were carried out with the objective of measuring the individual variation in feedblock intake for flocks of ewes containing a proportion of 2-year old ewes. These were carried out under both lowland and hill conditions.

Experiment 5.1. The individual intake variation for mature and 2-year old ewes given W290(76) under lowland conditions

Materials and Methods

The experiment was carried out during February and March 1976 on the University of Glasgow Farm, which is typical of many lowland units in the area, with a flock of 100 Greyface ewes of which 20 were 2-year olds. The expected start of lambing was approximately 8 March. The ewes were allowed access to an area of approximately 17 ha. All the ewes possessed a full compliment of incisor teeth for their respective ages.

Four W290(76) feedblocks were made available on the 31 January and new blocks were introduced to maintain a quantity of block material available to the ewes well in excess of the previous days consumption.

The W290(76) feedblocks contained 4·16 g chromium oxide/kg DM. Fourteen and 28 days after introducing the feedblocks the ewes were penned and rectal grab samples obtained from as many individual ewes as possible on each occasion.

Results

The mean daily intake over the duration of the Expt was 544 ± 17·2 g. There was no progressive increase in feedblock intakes as the lambing date approached.

Table 16. Expt 5.1. Individual variation in feedblock intake for a lowland flock containing a proportion of 2-year old ewes

	Mature ewes		2-year old ewes		All ewes	
	Sample 1+	Sample 2‡	Sample 1	Sample 2	Sample 1	Sample 2
Nos.	77	64	14	12	91	76
Faecal chromic oxide g/100 kg DM	428±27	505±33	169±61	171±64	388±27	453±32
CV%	56	54	135	129	66	64
% of individual values < 1g chromic oxide/ 100 kg DM	1.3	6.3	50	50	8.8	13

\+ ‡ 14 and 28 days, respectively.

Fifty percent of the 2-year old ewes sampled, 7 and 6 individuals for samples 1 and 2, respectively, had insignificant amounts of chromic oxide in their faeces and were judged not be be consuming feedblocks (Table 16). The proportion of mature ewes not consuming feedblocks (1 and 6% for the respective samplings) was much lower. The mature ewes had significantly ($P < 0{\cdot}001$) higher faecal chromic oxide concentrations than the 2-year old sheep at both sampling periods. However, when the 2-year old ewes which were evidently not consuming block were eliminated from the data, the mean concentrations 330 ± 88 and 326 ± 91 for samplings 1 and 2 respectively were not significantly different from the values for the mature ewes.

Experiment 5.2. The individual intake variation for mature and 2-year old ewes given RS feedblock under hill conditions

Materials and Methods

The experiment was carried out on the West of Scotland College of Agriculture hill farm at Crianlarich, Argyllshire. Kirton Farm is approximately 420 ha in area within a ring fence and rises from 222 to 740 m with a rainfall of 40 cm per annum. The farm outwinters about 600 Scottish Blackface ewes with a lambing rate of 94%. There was very little roughage available during the winter due to the two pasture system being operated which removed most of the grass in the summer. The analysis of a composite sample of the roughage gave 57·3 g CP and 341·6 g CF/kg.

RS feedblock was given on the hill during winter and the leaner ewes were progressively drawn onto the lower ground for more intensive husbandry. The blocks were sited at intervals over the hill and 3 blocks were put down at each site. New blocks were introduced when necessary so that the ad libitum situation was maintained.

On the 15 March 1976, 412 ewes were left on the hill after the first draw of poorer ewes. The mean daily consumption of the RS block was approximately 83 g DM/head with no other form of supplementation given. RHE feedblocks containing chromic oxide (3·65 g/kg) were now introduced.

On the 29 March, faeces were obtained from 80 of the ewes by grab sampling and the faeces analysed for chromic oxide. At this time 50% of the ewes were in too poor condition to stay on the hill and were drafted to lower areas. An assessment of the body condition of the ewes was made and the ewes divided into two categories moderate and thin condition.

Results

The individual variations in faecal chromic oxide (indicative of RHE feedblock intake) for both mature and 2-year old ewes in either moderate or thin condition are given in Table 17. The overall CV for faecal chromic oxide variation was 137%. The ewes in moderate condition had significantly ($P < 0{\cdot}05$) greater faecal chromic oxide concentrations, than ewes considered to be in thin condition. Two-year old ewes in moderate condition had higher (64 v. 36) mean faecal chromic oxide contents but the difference was not significant.

Approximately half the ewes sampled appeared to be consuming little or no feedblock. Most of the 2-year old ewes (88%) and a large proportion of the mature ewes (53%) in thin condition had faecal chromic oxide contents of less than 1 g/kg DM. Of the whole flock, the percentage of ewes with faecal chromic oxide values less than 1 g/kg DM was 32 and 70% for the ewes in moderate and thin conditions, respectively. There was no significant difference in faecal chromic oxide values for mature ewes in moderate condition and 2-year old ewes in moderate condition, nor for the mature and 2-year old ewes in thin condition.

Table 17. Expt 5.2. Individual variation in feedblock intake for a hill flock containing a proportion of 2-year old ewes

	Moderate condition			Thin condition			
Ewes	Mature	2-year old	All	Mature	2-year old	All	Overall mean
Nos	32	15	47	17	16	33	80
Mean faecal chromic oxide g/100 kg DM	82±16	64±17	76±12	32±14	36±20	34±13	41±6
CV%	100	103	108	180	256	220	137
% of individual values $<$ 1g chromic oxide/kg DM	31	33	32	53	88	70	48

Discussion

In the lowland situation (Expt 5.1) most of the mature Greyface ewes appeared to be consuming the W290(74) feedblocks given but only about half of the 2-year old ewes were consuming block. In the hill situation (Expt 5.2) when the Scottish Blackface ewes were given RHE feedblocks, only half the ewes sampled appeared to be consuming feedblock. These included a considerable proportion of both mature and 2-year old ewes in the flock. There was a tendency for the majority of thin ewes in both age groups to have lower faecal chromic oxide concentrations and a greater proportion of individuals with an insignificant amount of chromic oxide in the faeces. However, it was not known if these ewes were initially thin or they became thin because of their apparent failure to consume the blocks. Similarly, for the hill sheep in moderate condition, their superior condition might have been due to their apparently higher feedblock intake or alternatively they may have commenced the winter in better condition and maintained this independently from the block.

The findings of Expt 5.2 stimulated the extensive evaluation of different feedblock types on the performance of hill ewes, as briefly outlined in the general discussion for this section.

Although no comparative studies were carried out in Expt 5.1 and 5.2 with similar ewes given trough supplements, the results indicated that it is wrong to assume that feedblocks eliminate the problem of 'shy-feeders.' However in the few weeks before the start of Expt 5.1 it was observed that the 2-year old sheep were not consuming trough-given concentrates, which were readily accepted by the older sheep. It is probable that a large proportion of the sheep not consuming feedblocks, particularly in the hill situation also would not consume supplementary nutrients from troughs. It is unlikely however that the porportion would be in excess of the number of 'shy-feeders,' recorded here for the blocks. In the lowland situation (Expt 5.1) it was mainly the 2-year old ewes which failed to consume blocks, for the hill situation many of the mature ewes were also 'shy-feeders.'

It would be important to discover if by using a more palatable block, particularly for the hill situation, a greater proportion of the ewes would maintain condition and could therefore be left on the hill, thus freeing the in-bye areas for other uses and for restricting the purchase of brought in roughage. These aspects require further study.

E The individual intake variation for feedblocks and concentrates given in troughs for cattle

The results of Parts A, B and C of this section failed to substantiate the claim that the 'self-help,' system of providing extra nutrients in block form was a more precise means of supplementing stock than competitive trough feeding. In fact the 'hand-feeding,' system (troughs) showed invariably less individual variation in supplement intake, than when equivalent amounts of DM were taken from feedblocks. When the amount of trough space per head was restricted and competition increased, the amount of variation for the concentrate supplemented animals increased. Even under these circumstances there was usually less individual intake variation for trough given concentrates.

All this information was compiled using sheep. Part E of this section was concerned with comparing the individual variation in intake for the feedblock, concentrates (troughs) and cob techniques of supplementing cattle. The proportion of any group of cattle refusing to consume feedblock in a given situation was also studied in Part E. Individual intake estimations and comparisons were made under a variety of circumstances using cattle of different breeds, ages, live weights and physiological condition. In virtually all cases estimates of individual supplement intakes were made using rectal grab samples. The validity for using this technique and the likely degree of accuracy obtained are discussed in Expt 1.4 (Introduction, materials and methods). It was shown that the chromic oxide concentration in even a single rectal grab sample was a very good indication of relative feedblock intake within the group.

A series of small trials were carried out to record individual variation in feedblock intake by cattle including the proportion of animals completely refusing to consume feedblock. All the feedblocks used contained chromic oxide (7.98 g chromic oxide/kg DM for W291(76), 9·51 g chromic oxide/kg DM for the CSE). The important details of these trials are presented in Table 18. Further data on the individual variation in feedblock intake by cattle are given later in the thesis (see particularly Section 2, Expt 7.2 and Section 3, Tables 11.1 and 11.2). The results outlined in Table 18 suggest that it is incorrect to assume that all cattle will consume feedblocks. For example nearly 50% of the suckler cows given W291(76) had faecal chromic oxide concentrations less than 10% of the group mean and were consuming little or no block. At subsequent sampling date (Jan 1977) only 2 cows had faecal chromic oxide concentrations less than 10% of the mean. In every situation where an estimate of individual variation was made, one or more individuals were apparently not consuming feedblock. This agrees with most of the sheep experiments and places grave doubts on the efficiency of feedblocks as carriers of warble dressings, anthelmintics and particularly supplementary magnesium as a prophylactic against hypomagnesaemia. In some of the trials individual cattle occasionally had exceptionally high chromic oxide concentrations and accounted for a disproportionally large part of the mean. It may have been that these individuals were grossly over-consuming feedblock or had eaten very small quantities of roughage.

The results shown in Table 18 indicated that the individual variation in feedblock intake could be extremely large (CV 66 to 148%) therefore two, detailed experiments were carried out when individual variation in feedblock intake for cattle was compared with giving equivalent amounts of DM as concentrate pellets in troughs.

Expt 6.1. Individual variation in intake of W290(76) by Friesian heifers compared to concentrates given in troughs

Materials and Methods

Fourteen, 250 kg Friesian heifers were allowed access to a 7 ha field with virtually no grazing. The experiment took place during

Table 18. Individual variation in feedblock intake by cattle in a variety of circumstances during winter

Description of cattle and experimental conditions	Feedblock used and intake (kg DM/head/day)	Mean faecal chromic oxide g/100 kg DM	Individuals with chromic oxide 10% of the mean	CV%
Indoors				
7 pregnant Friesian dairy cows given hay plus concentrates	W291(76) 0.64 ± 0.1	200(17-440)+	1	65.9
Outdoors				
12(Hereford cross) heifers. Grazing (2ha) plus hay	W291(74)	85(1-575)	1	110.0
22(Hereford cross) cows. (450-550 kg). Poor grazing(5 ha)	W291(76) 0.32 ± 0.17	85(3-486)	10	147.6
The same cows. Poor grazing (20 ha) plus hay	W291(76) 0.86 ± 0.37	146(11-464)	2	83.2
12 reared calves Poor grazing(2 ha) plus hay				
6 smaller (125 kg)	CSE 0.68±0.1	322(48-554)	0	59.4
6 larger		290(43-426)	0	64.2

+ Range in faecal chromic oxide.

December 1976 and the weather conditions were in general cold with periods of sleet and snow. The animals were given a W290(76) feedblock plus barley straw. The feedblock contained 4·40 g chromic oxide/kg DM. Ten days after the introduction of the blocks rectal grab samples were taken from the heifers.

Over a subsequent 15-day period the heifers were given an allocation (0·61 kg DM/head/day) of a barley soya-bean meal pellet (170 g CP, 33 g CF, 17 g EE, 88 g ash/kg) containing chromic oxide (5·29 g/kg DM). The trough space allowed was 340 cm/head, measured along one side only (the other side of the trough was against a fence and prevented the cattle from using both sides of the trough). On day 15 the heifers were again grab sampled.

Results

The mean faecal chromic oxide concentrations for the heifers were 100 and 170 g chromic oxide/100 kg faecal DM for the feedblock and concentrate samplings, respectively. The coefficient of individual variation (57·3%) for the heifers when given blocks was considerably in excess of the concentrate value (30·6%). Therefore the provision of nutrients in feedblock form under the circumstances of Expt 6.1 was less precise than when an equivalent amount of DM was given in troughs.

Expt 6.2. Individual variation in intake of W290(76) and concentrates given in troughs

Nineteen Hereford cross weaned (8 month old) suckler calves were divided into groups (R and W) of 10 and 9 animals, respectively. The mean live weight was about 215 kg. Group R and W animals were allowed access to fields of size 4·0 and 2·5 ha respectively.

The experiment was carried out over 6 consecutive weeks from 27 Oct to 7 Dec. During the first 2 weeks the grass supply could be considered 'excellent'; during the second 2 weeks 'moderate' and during the third 2-week period 'sparse.' In the third 2-week period hay was given (1 kg/

head/day). There were no marked changes in weather conditions between the periods.

During weeks 1, 3 and 5 both groups of cattle were given W290(76) feedblocks which were weighed daily and replenished when about 5 kg of the block remained. The block residue was removed. During weeks 2, 4 and 6 the cattle were given a fixed daily allocation of chromic oxide-containing barley cubes with ample trough space (140 cm/head). The amounts given were the appropriate mean DM intakes of the block during the previous week. These were 0·14, 0·26 and 0·27 kg DM/head/day during weeks 2, 4 and 6.

A single faecal grab sample was obtained from each animal on the last day of each weekly period.

Subsequently the cattle were housed and received individually a fixed concentrate allocation (0.26 kg DM of a chromic oxide-containing barley cube) but with group access to hay. A rectal grab sample was obtained from each animal at the end of the 7-day feeding period.

Results

The mean feedblock intakes and concentrates given, faecal chromic oxide concentrations and the respective coefficients of variations in Expt 6.2 are presented in Table 19.

The intake of feedblock increased from about 0·14 kg DM/head in period 1 when the grass supply was ample to 0·27 kg DM/head in periods 3 and 5 as the amount of available grass declined. The mean intakes for both group R and W were very comparable indicating that a group of about 10 animals gives a good duplicate. The inter-day variations in block intake were also very comparable for each group and increased as the grass supply declined.

Table 19. Expt 6.2. Supplement intakes and faecal chromic oxide concentrations (g/100 kg DM)

	W290(76) Feedblock						Concentrates				
Period	Group	Mean intake kg DM/day	CV%	Mean faecal chromic oxide	CV%	Period	Group	Mean intake kg DM/day	Mean faecal chromic oxide	CV%
1	R	0.14	31.2	49	81.4	2	R	0.14	37	63.1
	W	0.13	32.2	101	78.7		W	0.14	40	50.0
3	R	0.26	35.8	108	109.0	4	R	0.26	86	42.8
	W	0.29	44.3	124	77.0		W	0.26	90	57.3
5	R	0.26	50.2	82	78.3	6	R	0.27	105	66.4
	W	0.28	46.1	106	64.7		W	0.27	119	48.0

The analysis of the faecal grab samples showed that the coefficients of variation for these two groups of 10 animals were consistently in the same order. There was a greater mean CV for feedblock supplementation (81·6 ± 6·0%) than for the concentrates given in troughs (54·6 ± 3·8%). This difference was significant $P < 0{\cdot}05$.

When the calves were housed and individually given 0·26 kg DM/head of a barley cube containing chromic oxide and hay ad libitum, the coefficients of variation for faecal chromic oxide were 20·2 and 14·3% for groups R and W, respectively. Thus when the major factor influencing faecal chromic oxide is removed (variation in chromic oxide intake) the remaining variation can be attributed to errors inherent in the technique and variation in roughage intake and diet digestibility. The results obtained when the calves received a constant daily input of chromic oxide illustrate that a considerable amount of the variation measured outdoors can be reasonably apportioned to variation in supplement (chromic oxide) intake. Therefore the significantly greater variation for giving nutrients in feedblock form is likely to be a real effect and not confounded by errors in the grab sampling technique.

The results of Expts 6.1 and 6.2 were consistent with the data obtained for sheep (Parts A, B and C of Section 1) i.e. in virtually every circumstance feedblocks are a less precise means of giving nutrients to stock, than concentrates given in troughs. In a further trial a group of 20 adult beef-type cows were given a daily allocation of about 1·1 kg DM/head of cattle cobs (2·11 g chromic oxide/kg), the CV for faecal chromic oxide concentration was 68% with a range in concentrations 20 to 145 g chromic oxide/100 kg DM (mean 44 g). This is lower than for most feedblock comparisons but in excess of those for 'hand-fed' concentrates. Further work is required on the individual variation in intake of cobs given to cattle relative to other methods of giving additional nutrients.

General Discussion

The results of Section 1 clearly show that for both cattle and sheep it is incorrect to assume that when feedblocks are continuously available to the stock a more uniform individual intake within the group is achieved. In fact the opposite appears to be the true situation. In Part E of this Section the mean CV for individual feedblock intake was significantly greater than when equivalent amounts of DM were given to cattle as concentrates in troughs. When the results of Parts A, B and C of the present Section are considered together, the mean CV for individual feedblock intake by sheep (20 combinations of different feedblocks, situations and levels of consumption) was 55·1%. In these experiments the same or similar sheep were also given 'hand-feeding' in 21 differing ways, including various trough space allowances (generous to very restricted) and amounts of concentrate allocated (both on a regular and irregular basis). The mean CV for individual intake from troughs (39·2%) was significantly ($P < 0.05$) less that for feedblocks. Therefore for both cattle and sheep, 'hand-feeding' using troughs is likely to allow a more uniform individual DM intake within a group than 'self-feeding' using feedblocks. It appears to be only when trough space allowance is severely limiting and/or the amount of concentrate allocated is unrealistically low, that feedblocks are superior to 'hand-feeding' in terms of individual precision of intake. The limited amount of data obtained for comparisons between cobs and either feedblocks or 'trough-given' concentrates shows that cobs are at least as precise as concentrates (given in troughs) and invariably superior to feedblocks. It cannot always be assumed that in practical farm situations blocks would be continuously available, replaced when less than a full day's supply was left and cleaned if required as was the case in these experiments. Such factors could only tend to increase the individual variation in intake.

The factors which influenced the absolute amounts of feedblock consumed by individuals within the group appeared to be completely different from those which influenced the intake of 'hand-fed' supplements and vice versa. For example, the possession of horns and above average body size (factors which generally contribute to an elevated position in the 'peck order') enabled individuals to consume 'hand-fed' nutrients well in excess of the group mean. Dental status was however not important. When feedblocks were given, dental status was of fundamental importance in determining the absolute amounts of feedblock DM consumed by individuals. Characteristics required for an above average intake in the 'hand-fed' situation appeared to be of little consequence. Therefore the claim that concentrate 'shy-feeders' will acquire a fair share of the additional nutrients on offer when these are given as feedblocks may perhaps be partly justified. However, the results of Expt 5.1 showed that many of the 2-year old ewes not competing for 'hand-fed' nutrients were also not consuming feedblocks. What is more important is that a proportion of the animals readily consuming 'hand-fed' nutrients will become 'shy-feeders' with feedblocks for reasons connected with feedblock hardness and dental status or the unpalatable nature of the blocks in general. The net result appears to be an increased individual intake variation within the group. This is a serious obstacle to the use of feedblocks as carriers of special therapeutic agents such as anthelmintics or warble dressings and particularly their use as carriers of supplementary magnesium. The evaluation of feedblocks in this latter role is examined in detail in Section 3, Part C.

It was never the intention of the studies in Section 1 or for this thesis in general to particularly compare individual feedblock products from different manufacturers. One of the principal objectives however was to compare the 'self-fed' system of giving additional nutrients with the more traditional 'hand-fed' system. It was also the intention to compare the suitability or otherwise of the low intake supplement-type feedblocks (e.g. Rumevite) with the more flexible intakes offered by the substitute-type feedblocks (e.g. Wintawell and Colborn-type blocks). Under the low ground circumstances of the experiments of Parts B and C of this Section, the lowest individual feedblock intake variations were obtained for the substitute-type feedblocks CSE. That the CSE block gives a lower individual intake variation, than the supplement-type feedblocks is not surprising as it is inherently more palatable. Although a more palatable feedblock might be overconsumed by certain greedy individuals, with a consequent increase in individual variation within the group; the apparent superiority to the other substitute-type feedblocks studied probably reflects a more subtle difference in formulation and/or manufacturing process. The CSE and W290-type feedblocks were usually consumed at about the same mean level. The W290-type blocks however tended to be grossly overconsumed by some individuals and yet appeared to be very unattractive to other sheep.

It is likely that most feedblocks given to sheep are used in the hill situation, in the six to eight week period before parturition and usually during the subsequent two to four weeks of lactation. The results of Expt 5.2 showed that under a hill situation (March 1976), where shortage of roughage was an underlying feature, the particular feedblocks given (RHE) or the block system (i.e. allocation and distribution on the hill etc.) in general, were unsuitable. Nearly half the ewes sampled in late pregnancy had no or very small amounts of chromic oxide in their faeces; the 2-year old ewes (gimmers) in particular seemed not to be consuming the blocks. The ewes with the lowest amounts of faecal chromic oxide tended also to be in poorest condition. At the time of faecal sampling 50% of the ewes (of a total of about 400) were judged to be in too poor condition to remain on the hill and were drafted to in-bye fields. Under these particular circumstances the provision of additional nutrients in the particular feedblocks was not very successful. The shortage of roughage on the hill was undoubtedly the major cause of the poor condition of many of the ewes, but the alarmingly high proportion of apparently 'shy-feeders' in the flock could only have exacerbated the variation in body condition.

It is well appreciated that scarcely any two hill farming situations are even remotely similar. There is a great diversity of factors which influence individual flock performance such as the inherent fertility of the ground, herbage quality and quantity, climatic factors, physical nature of the hill, management factors etc. Arguments exist concerning both the quantitative amounts of supplementary nutrients (if any) required in the critical late pregnancy/early lactation periods for the hill ewe and also the qualitative composition of these supplements. With so many dynamic factors involved such as the amount and quality of the available roughage, the body condition of the ewes in a given year and the expected lambing percentage, it is extremely doubtful if these arguments can ever be satisfactorily resolved. Also until more information is available concerning the diet selected by the hill ewe, rather than what is left unconsumed, during these critical periods in both quantitative and qualitative terms, such arguments are somewhat academic.

It is beyond the scope of this Section to enter into discussion on these aspects of nutrition. Hypothetically, if the required input of additional nutrients in a given situation could be accurately defined both quantitatively and qualitatively a further series of arguments would ensue concerning the most efficient means of giving these inputs. Ultimately this would involve 'hand-feeding' versus 'self-feeding.' In the final analysis the individual farmer determines how his stock are to be given supplementary nutrients (if any) and with agricultural labour becoming increasingly scarce and expensive feedblocks are often chosen. Convenience to the stockfeeder appears to be the most important criterion regarding the system of giving nutrients and frequently, the nutritional well-being of the stock is compromised to a greater or lesser extent in the realisation of this goal.

In the winter of 1977 a series of farm trials were carried out with the object of assessing the suitability of 'self-help' feedblocks as carriers of additional nutrients to pregnant and lactating hill sheep. Twelve different farms in Scotland were used in several different geographical locations. (Ayrshire, Dumfriesshire, Argyllshire, Perthshire and Stirlingshire). A common feature to all farms was the hill situation (all qualified for full hill sheep subsidies). Most of the sheep involved were pure Scottish Blackface although two farms had cross-bred ewes (Scottish Blackface ♀ x Swaledale ♂). Some of the farms were firmly established users of feedblocks; others were new to block feeding. Feedblocks of either the Rumevite, Wintawell or Colborn-type were normally given and the trials were integrated with the minimum disturbance into the normal management systems of the flocks. Expt 5.2 was a typical example of such a trial. Approximately seven days before an expected gather of the ewes, feedblocks similar in every other way to those normally given were introduced, apart from an inclusion of chromic oxide (about 10 g/kg DM). Rectal grab samples (for chromic oxide) were subsequently obtained. Records were also kept of feedblock intakes, method of dispersal of the blocks and pattern of block consumption. On some of the farms performance data was concurrently being compiled by the West of Scotland Agricultural College and it is intended to relate this to the faecal chromic oxide concentrations.

In total, nearly 5000 rectal grab samples have been taken and the results will be published in full when complete. Special emphasis will be placed on proportion of a particular age group totally refusing the blocks and also individual variation in block intake in general. To date the results from only three farms have been analysed, and these show widely constrasting amounts of individual variation. At one farm, (Crookburn, Elvanfoot, Dumfriesshire), of a hirsel of about 180 Scottish Blackface ewes, 124 rectal grab samples (15 Feb) were obtained. The expected lambing date was about April 10th and the ewes were in excellent condition (average body score 2 to 2½). Roughage was abundantly available with a proportion of heather. The maximum altitude was 550 m above sea level. The sheep had been given RS blocks for about 14 days prior to sampling and were in their second season of receiving blocks. Only 7 ewes (6% of those sampled) had chromic oxide concentrations less than about 1 g/10 kg of faecal DM. The overall mean faecal chromic oxide concentration was 186 g/100 kg faecal DM with an exceptionally low CV of 48·8%.

At a second farm (Lurg, Fintry, Stirlingshire) 130 Scottish Blackface x Swaledale ewes which had been receiving CSE feedblocks for several weeks were sampled (28 Feb). The sheep on this particular hirsel had received feedblocks during several previous years. The expected lambing date was about 20 April and the ewes were generally in good condition (body score 2). Moderate quantities of mainly grass roughage were available and the maximum altitude of the hill was about 370 m. Of the 103 grab samples obtained, 23 ewes (22·3% of the flock) had chromic oxide concentrations less than 1 g/10 kg faecal DM and were considered to be consuming little or no block. The mean concentration was 95 g chromic oxide/100 kg faecal DM with a CV of 89·3%.

On the third farm (Upper Gattaway, Abernethy, Perthshire) which was more typical of an upland stock-rearing farm rather than a true hill unit, W290(76) feedblocks were given to a group of 170 Blackface ewes (most were over 5-years of age and some had broken mouths). The sheep had never previously received feedblocks and apart from the week preceeding grab sampling when ad libitum blocks were given, the supply was rationed for economic reasons. The amount of roughage available to the ewes was extremely small and hay was additionally given. The expected lambing date was about April 20. These ewes were in very poor condition (average body score 1 to $1\frac{1}{2}$) and the winter had been severe with prolonged periods of snow cover. On the 15 March, 141 ewes were sampled of which 37 (26·2% of those sampled) had chromic oxide concentrations less than 1 g/10 kg faecal DM. The mean faecal chromic oxide concentration was 108 g/100 kg faecal DM and the CV was 119%.

Together with the data obtained from Expt 5.2 it would be unwise to emphasise these results under hill conditions until a full set of data is available. For example, the RHE feedblocks given in Expt 5.2 seemed unsuitable for that particular situation where roughage was very scarce. However, at Crookburn the RS feedblocks were apparently consumed by virtually all the ewes and the amount of individual variation in intake was exceptionally low. Roughage was here abundantly available but the hirsel was unusual in being very long and narrow. As the blocks were spaced along its length, this may have contributed to the exceptionally uniform pattern of individual intake. Thus feedblocks of the same type (supplement philosophy) have produced a contrasting result in two different situations. It is possible that this inconsistent pattern of performance will be repeated on other farms and for the other feedblock types studied. Careful examination of the various situations is then required to identify, if possible, the factors responsible for the success or otherwise of a particular feedblock-environment interaction.

SECTION 2

FACTORS AFFECTING THE TOTAL GROUP INTAKE FROM FEEDBLOCKS

Introduction

The fundamental difference between the 'self-fed,' method of providing nutrients such as the giving of blocks and the 'hand-fed' method is that in the former case the stock per se ultimately determine the total quantity of material to be consumed, if the total supply is not restricted. This may be influenced by a whole variety of factors inherent in the group of stock, the block itself, the external circumstances, such as climatic variables, affecting both and the manipulations made by the stockfeeder to effect a controlled level of intake. When a 'hand-feeding' system of giving nutrients is practised the situation is far less complex, providing the material given is reasonably palatable and rapidly ingested, the total amount consumed by any group of animals is governed precisely by the stockfeeder.

In Section 1, Part B it seemed that the inter-day variation in total group intake was likely in some circumstances to be a contributory cause of the high variation in individual intake within the group. In only one report (Ducker and Fraser, 1975), has any attempt been made to define and quantify the factors influencing inter-day variation and the absolute level of block intake attained in a given situation. They showed that the intake of Wintawell (1974)-type feedblocks decreased significantly as ambient temperature dropped to around $0^{o}C$ and that intake of the blocks increased when there was snow cover.

The manufacturers of feedblocks give approximate recommendations for the intake of their respective products. Examples of these are given in Table 20 for different classes of stock. Some manufacturers admit to the imprecise nature of these estimates, while others are confident that the actual intakes achieved in practice will coincide closely with their recommendations. It is possible and indeed likely that there are instances when feedblocks are not on ad libitum offer and are effectively rationed due to strict adherence to the manufacturers feeding recommendations by the stockfeeder.

The major objectives of Section 2 were to define the factors affecting the level of feedblock intake attained by a group of stock in a given situation, and the extent of inter-day variation and factors influencing this.

Table 20. Feedblock intakes as recommended by the manufacturers (g fresh matter/day)

Feedblock	RS	W290(74)+	W291(74)+	CSE	CC
Class of stock					
Hill ewes	100	110-130	90-100	110	-
Lowland ewes	130	210-270	130-160	170-220	-
Suckler cows	800	650-810	360-400	-	450-900
Cattle 1-3 years old	650	540-650	400-460	-	450-680

+ The recommended intakes of W290(76) and W291(76) are essentially the same.

The DM coefficients for feedblocks are usually in the range 0·82 to 0·84 and to maintain consistency with the rest of the thesis feedblock intakes in this Section have been in future expressed as g DM/head. Much of the information included in this section is ancillary data obtained from other experiments or results of several small scale trials which have been combined together. Some of the factors commented upon which are judged to influence feedblock intake are not supported by objective scientific data due to the difficulties of accumulating facts under extensive field conditions and the limited resources available.

Before any detailed investigations into the factors affecting the total group intakes of feedblocks were commenced, the level of intake attained by stock under a wide variety of circumstances was measured, in order to assess whether a regular daily intake could be obtained from feedblocks. This involved giving W290(74), W291(74) and RS feedblocks to cattle and sheep under housed and field conditions. Some of the results obtained for sheep are presented in Table 21. Each trial was carried out over a period between 14 to 60 days.

Table 21 clearly shows that the absolute intake of feedblock by any group of sheep depends principally upon the circumstances under which it is given and that intake is not controlled precisely by the formulation and manufacturing process of the block. A similar variation in mean intake was obtained for other feedblocks; for example the intake of RS feedblock was negligible when given to suckler cows at spring grass (Expt 11.1) but had exceeded 600 g/day over the preceeding 14-day period, when the cows were yard-housed and given silage. The intake of the RS feedblock was greater than 400 g/day for housed wethers given straw alone (Expt 8.2) but less than 70 g/day for ewes outside at grass in the autumn. Therefore, it is only when feedblocks are actually given to the stock that an intake level can be assessed. The recommended intakes given by the manufacturers (Table 20) are only very approximate estimates and may be totally misleading unless rationing of feedblocks is carried out and the ad libitum situation dispensed with. This itself is not conducive with some of the claimed advantages for block feeding such as allowing the 'shy-feeders' the maximum opportunity to consume feedblock nutrients. The rationing of blocks may be particularly serious when the block is being used as a magnesium carrier, where constant availability of magnesium is essential for the system to be effective.

Table 21 also shows that although the absolute intake of a feedblock varies greatly, the relative intakes for two different

Table 21. A comparative assessment of the intakes of two feedblocks differing in physical hardness (W291(74) and W290(74)) under a variety of circumstances under both housed and field conditions

Description of stock and other foods given.	W291(74)	W290(74)	Ratio of intakes
Outdoors			
50 Scottish Blackface ewes poor grazing (0.5 hs), hay + concentrates	9 ± 2	23 ± 9	1 : 2.6
50 Scottish Blackface ewes, poor grazing (1 ha) hay + concentrates	17 ± 2	47 ± 8	1 : 2.8
30 Greyface ewes poor grazing (5 ha) + hay	42 ± 13	90 ± 29	1 : 2.1
16 Greyface ewes (Expt 3.3) poor grazing (0.5 ha) + hay	175 ± 21	441 ± 28	1 : 2.5
Indoors			
7 Suffolk cross wethers, distillery siftings + concentrates	159 ± 10	393 ± 18	1 : 2.5
16 Greyface ewes (Expt 2.1) hay ad libitum	255 ± 19	626 ± 45	1 : 2.5
Groups of 16 Greyface ewes in individual pens (Expt 2.4) hay ad libitum	647 ± 26	797 ± 51	1 : 1.23

feedblocks (albeit manufactured by the same process) are surprisingly constant. The intake ratio of the W291(74) to W290(74) was always between 1 : 2·0 and 1 : 3·0 with one exception, when the feedblocks were given under somewhat artificial circumstances. This was when ewes were individually penned (Expt 2.4) and given W 290(74) or W291(74) feedblocks and the intake ratio between the blocks narrowed sharply (1 : 1·2). This was due to the high consumption of W291(74) rather than a low W290(74) intake. The possible reasons for this increase in intake have been discussed in Section 1, Part A but they probably reflect an increased provision of block surface area per ewe and the boredom behaviour of closely confined sheep.

Table 21 illustrates some of the other possible contributory factors affecting the absolute feedblock intake in any situation. There appears to be a reluctance of the Scottish Blackface ewes here to consume blocks, which is consistent with the findings in Section 1 Part D (Expt 5.2), when 50% of a flock of this breed under the particular hill conditions seemed not to be consuming the RS feedblock. It may also be partly due to the provision of concentrates which may have reduced the appetite of the ewes for block. The intakes of both W290(74) and W291(74) tend to increase as the size of the enclosure decreases. In general, the intake of any feedblock is greater under housed against field conditions. This was the case for all the feedblocks examined in this thesis unless some overriding constraint was imposed, such as restricting the surface area available to the housed stock by containers.

Within the mean intake data presented in Table 21 there was often considerable variation in intake between days. The results of Ducker and Fraser (1975) indicated that one possible cause of this was fluctuations in the weather. Therefore in the present studies the effect of climatic variables on the intake of feedblocks under various circumstances was investigated.

A The effect of climatic variables in the intakes of feedblocks

Most of the information on the effect of weather on block intakes was gathered on the University of Glasgow, Veterinary Field Station, Cochno Farm, Dunbartonshire, Latitude 56°N, 230 to 280 m above sea level. In many instances the feedblocks investigated were superimposed upon the routine nutritional management of the commercial stock on the farm. Therefore precise control of the experimental conditions was seldom achieved because of other management factors. In many of these experiments numerous other factors affecting feedblock intake besides climatic variables were isolated and have been mentioned when appropriate.

Experiment 7.1. Climatic factors influencing the intake of feedblock by sheep

The following feedblocks were given to various groups of Greyface ewes during the winters of either 1975 or 1976, W290(74), W291(74), RS and RHE (the chemical composition of the feedblocks used was as shown in Table 1). The climatic variables measured were rainfall, days when there was snow cover and mean daily temperature. A description of the recording techniques used is contained in the Materials and Methods section of the Introduction (page 70). The total group intakes of feedblocks were recorded by daily weighing (09.00 to 10.00 hr) using a 25-kg spring balance. This coincided with the r eading of the temperature and rainfall data. A new block was introduced when less than the previous days consumption of block material remained,or when less than 5 kg of material was on offer. Any block residues were removed. In some trials (with chromic oxide containing blocks) the animals were rectally grab sampled and the resulting faecal samples analysed for chromic oxide content.

Results

The inter-day variation in total group feedblock intake was considerable for all the feedblocks examined, especially for the W290(74) and W291(74) blocks. Even when mean intakes were expressed as a 3-day rolling mean there were still considerable fluctuations in intake with time. The description of the conditions under which the blocks were given, the mean daily intakes and any effect of the climatic variables on block intake are given in Table 22.

Table 22 shows that only for some feedblocks, and even then not on every occasion, was a significant effect of rainfall and/or temperature on feedblock intake recorded. There was no significant effect of either rainfall or mean daily temperature on the intake of W290(74) and W291(74) feedblocks. However the mean intake of 259 $\pm$ 17 and 135 $\pm$ 7 g DM/head for W290(74) and W291(74) over the 24-hr period immediately following the introduction of a new block was significantly ($P < 0{\cdot}001$) greater than the mean intake over subsequent 24-hr periods (87 $\pm$ 5 and 37 $\pm$ 11 g DM/head respectively). When two feedblocks instead of the single block were given to these ewes, the mean intakes (250 $\pm$ 28 and 97 $\pm$ 10 g DM/head) were increased by 90 and 35%, respectively, for the W290(74) and W291(74) feedblocks. This difference was significant ($P < 0{\cdot}001$) for the W290(74) feedblock.

In both winters when the effect of mean daily temperature on RS intake was examined a significant, negative correlation was obtained. The mean daily intake of RS appeared to decrease as the temperature fell towards $0^{\circ}C$. In the trial during late winter (1976) the mean daily intake of the RS feedblock on days when the mean temperature was less than $2^{\circ}C$ (52 $\pm$ 3 g DM/head) was significantly ($P < 0{\cdot}001$) lower than days when the mean temperature exceeded $2^{\circ}C$ (105 $\pm$ 7 g DM/head). A significant ($P < 0{\cdot}01$), positive correlation, between the mean intake of RS and rainfall was obtained during February 1976 but not for the previous year.

Table 22. The effect of rainfall and temperature during January to March on the mean daily intake of feedblocks by sheep under a variety of circumstances

Description of animals and experimental conditions	Feedblock	Mean daily intake (± SE) g DM/head	Mean faecal chromic oxide concentration g/100 kg DM	Effect of rainfall and temperature on feedblock intake
30 Greyface ewes given sparse grazing + concentrates (50)+	W290(74)	131 ± 15	88, Range 20-170 (49%)++	NS
30 Greyface ewes given sparse grazing + concentrates (50)	W291(74)	71 ± 11	44, Range 9 -130 (69%)	NS
40 Greyface ewes given winter grazing (16)	RS	96 ± 7	—	Significantly ($P < 0.05$) correlated ($r = -0.62$) with temperature and rainfall ($P < 0.01$) $r = 0.67$
30 Greyface ewes winter grazing + hay + concentrates (40)	RS	76 ± 5	—	Significantly ($P < 0.001$) correlated ($r = -0.54$) with temperature. No significant correlation for rainfall
30 Greyface ewes winter grazing + hay + concentrates (54)	RHE	161 ± 9	—	NS

+ Number of days over which measurements were taken. ++ CV%.

The data on the effect of climatic variables on the intake of RS feedblocks by sheep were then combined for both years and grouped into days when there was no rain (dry days), days when the rainfall was less than 1 mm (light rain) and days when the rainfall exceeded 1 mm (rainy days). Linear regression equations (Fig.5) of mean daily feedblock intake against temperature for the dry days and days when light or substantial rain fell were calculated. These were as follows

a) Dry days

$y = 3{\cdot}16x + 66{\cdot}6$ SE of $b = 3{\cdot}23$

b) Rainy days

$y = 9{\cdot}09x + 76{\cdot}2$ SE of $b = 4{\cdot}75$

where x = Mean daily temp $^{\circ}C$
y = RS intake g DM/head

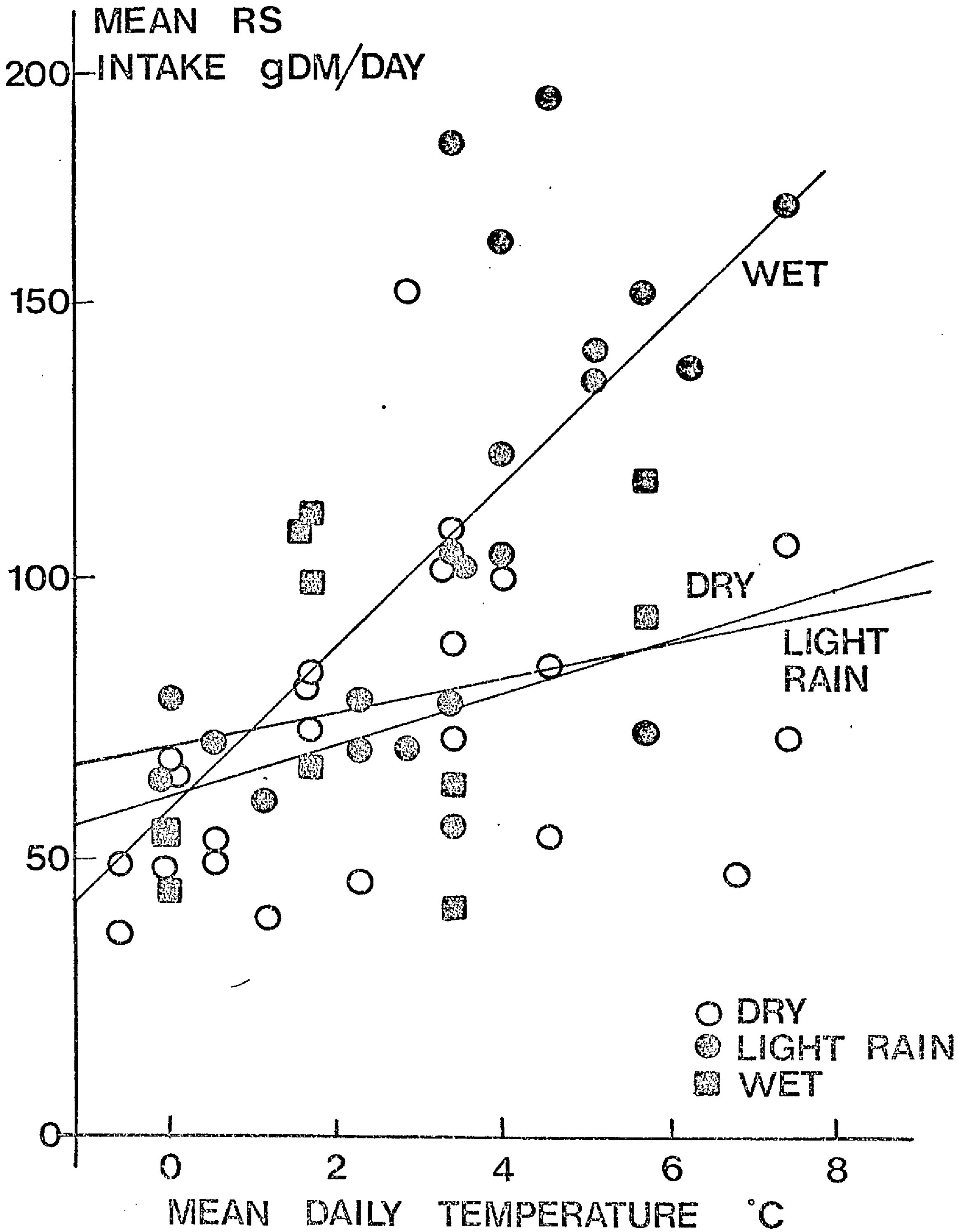
c) Light rain days

$y = 2{\cdot}10x + 74{\cdot}1$ SE of $b = 3{\cdot}20$

The results for days when only light rain fell were omitted from the comparisons involving the effect of rainfall on RS intake. The slope of the regression line for rainy days was positive, while for dry days there was a strong indication that the slope was positive. The mean daily DM intakes of RS feedblock on dry days, light rain days and rainy days were 75 ± 7, 79 ± 9 and 107 ± 8 days, respectively. The difference between rainy days and dry days was significant at $P < 0{\cdot}01$ and between rainy days and days of light rain at $P < 0{\cdot}05$.

The effect of the interaction between rainfall, temperature and feedblock consumption was further examined by comparing the regression lines for dry days and rainy days. There was a probability in excess of 0·98 that wet weather increased the intake of RS at all temperatures between 2·8 and 10°C. Below 2·8°C the effect of wet weather was minimal and above 10°C was outside the range of temperatures studied. There seemed to be no substantial dependence of feedblock intake on the actual amount of rainfall, once the days when light rain fell had been omitted.

Fig.5 Expt 7.1 The effect of mean daily temperature °C on the mean daily intake (g DM/head/day) of RS feedblocks by groups of pregnant ewes at winter grazing for dry days and days with light rain (< 0.1 mm) or wet days.



MEAN RS
INTAKE gDM/DAY
200
150
100
50
0
WET
DRY
LIGHT
RAIN
DRY
LIGHT RAIN
WET
0
2
4
6
8
MEAN DAILY TEMPERATURE °C

Over the period studied there were no significant correlations between any of the climatic variables and the voluntary intake of RHE feedblocks.

The effect of snow cover on feedblock intake could only be assessed in a few situations due to the absence of a prolonged period of continuous snow cover. Therefore the data examined refer to single days or short periods when snow cover existed, which have been combined together and compared with days when the ground was clear. It was noticed that the intake of all the feedblocks given to sheep, invariably increased when snow prevented the stock from grazing. For example, the combined mean intakes of RS and RHE from Expt 4.2 on days with snow cover (105 $\pm$ 4 g DM/head) were significantly ($P < 0.001$) greater than for other days (70 $\pm$ 5 g DM/head).

Experiment 7.2. The effect of climatic variables on the voluntary intake of feedblocks by cattle

A series of trials were carried out with the intention of assessing the effect of climatic variables and other factors on the intake of feedblocks given to cattle of various ages under varying circumstances.

Trial I

Thirty Friesian heifers (18 to 24 months old) plus a Hereford bull were outwintered on an area (0.2 ha) of rock-strewn ground, providing considerable natural shelter but virtually no grazing. The trial was carried out between 25 February to 5 May 1976. The cows received ad libitum good quality silage plus CC feedblock (Table 1 for chemical composition) until 23 April when an enclosure (6 ha) of sparse grazing was made available. The mean daily intake of feedblock was monitored by daily weighing and a new feedblock introduced when less than the previous 24-hr consumption remained. The feedblock residues were removed.

On 25 March the cattle were rectally grab sampled (the CC feedblock contained 10·3 g chromic oxide/kg DM).

Trial II

Two groups of 6, 200 kg weaned (Hereford cross) calves were given access to fields A and B. The experiment took place from 3 December 1975 to 8 January 1976. Field A initially contained only sparse grazing while field B contained good grazing which was quickly consumed and by about 17 December 1975 it resembled field A. The groups of cattle were each given a W291(74) feedblock containing (2·51 g/kg) chromic oxide. New feedblocks were introduced on 3, 11 and 16 December and 2 January to both groups. The feedblocks were weighed daily. On 11 December 1975 and 8 January 1976 the cattle were rectally grab sampled.

Trial III

Two groups of 200 kg weaned suckler (Hereford cross) calves were given access to the same fields (A and B) as Trial II. The experiment took place from 27 October 1976 to 21 January 1977. Both fields initially offered good, clean grazing. Trial III included and was a continuation of Expt 6.2 (Section 1) and a more detailed description of the experimental procedure is included on page 134. On 1 December 1976 there was insufficient grass available for the calves and about 1 kg/head/day of hay was given. At times during the experimental period both groups of calves were given a W290(76) feedblock (no container) containing chromic oxide. The durations when blocks were given were, 27 Oct to 3 Nov, 10 to 17 Nov, 24 Nov to 1 Dec, 8 to 27 Dec and 27 Dec to 21 Jan (one group only). The blocks were weighed daily and replenished as in Trial I.

Trial IV

Twelve beef-type cows (mainly Hereford cross) all with calves at foot (calving date, August 1975) were alternated around several fields of permanent pasture from 12 Oct (1975) to 10 Jan (1976). On 7 Nov, four additional cows with calves at foot were included in the group. From 2 Nov about 2·5 kg hay/head/day was given and increased to 3·75 kg/head/day from 22 Dec. Throughout the experimental period RHE feedblocks (in a purpose-built container unless otherwise stated) were on offer. The mean intake of block was monitored by daily weighing and the eventual level of consumption required a new block to be introduced daily or on alternate days. On 2 consecutive days the blocks were weighed at six approximately 4-hourly intervals (04.00, 08.00, 12.00, 16.00, 20.00, 24.00 hrs) to determine pattern of feedblock consumption within a day.

Trial V

This trial was carried out from 2 March to 21 April using the 14 remaining lactating suckler cows used in Trial IV. Throughout the trial the cows were grazing a field (20 ha) containing generally sparse grazing but with some patches of coarse roughage. In addition they received about 3 kg/head/day of moderate quality hay and W291(76) feedblocks. From 2 March to 9 March a single W291(74) feedblock was made available in a circular tin which served to keep the block clean. From 10 March to 19 March the container was dispensed with and the blocks still given singly. On 23 March, four W291(76) feedblocks were put on offer (with no containers) which was equivalent to the feedblock material consumed in 7 days when the blocks were provided singly. On 30 March (i.e. after 7 days) any residues remaining were collected up and 4 new W291(74) feedblocks introduced. On 9 April (i.e. after a further 10 days) the residues were again collected and a further 4 new blocks put out, but now given in tin containers (with the intention of keeping the blocks clean and allowing a stable base to prevent pushing of the block). On 14 April one block remained virtually untouched and was left with the cattle and 3 replacement blocks (in containers) were introduced. On 21 April the trial was discontinued.

Over the experimental period individual feedblocks were weighed daily (between 09.00 and 10.00 hr) and mean daily feedblock intakes calculated for when single blocks were given with or without containers and when a weeks supply of blocks (put out in one day) was given with and without containers.

Results

Trial I

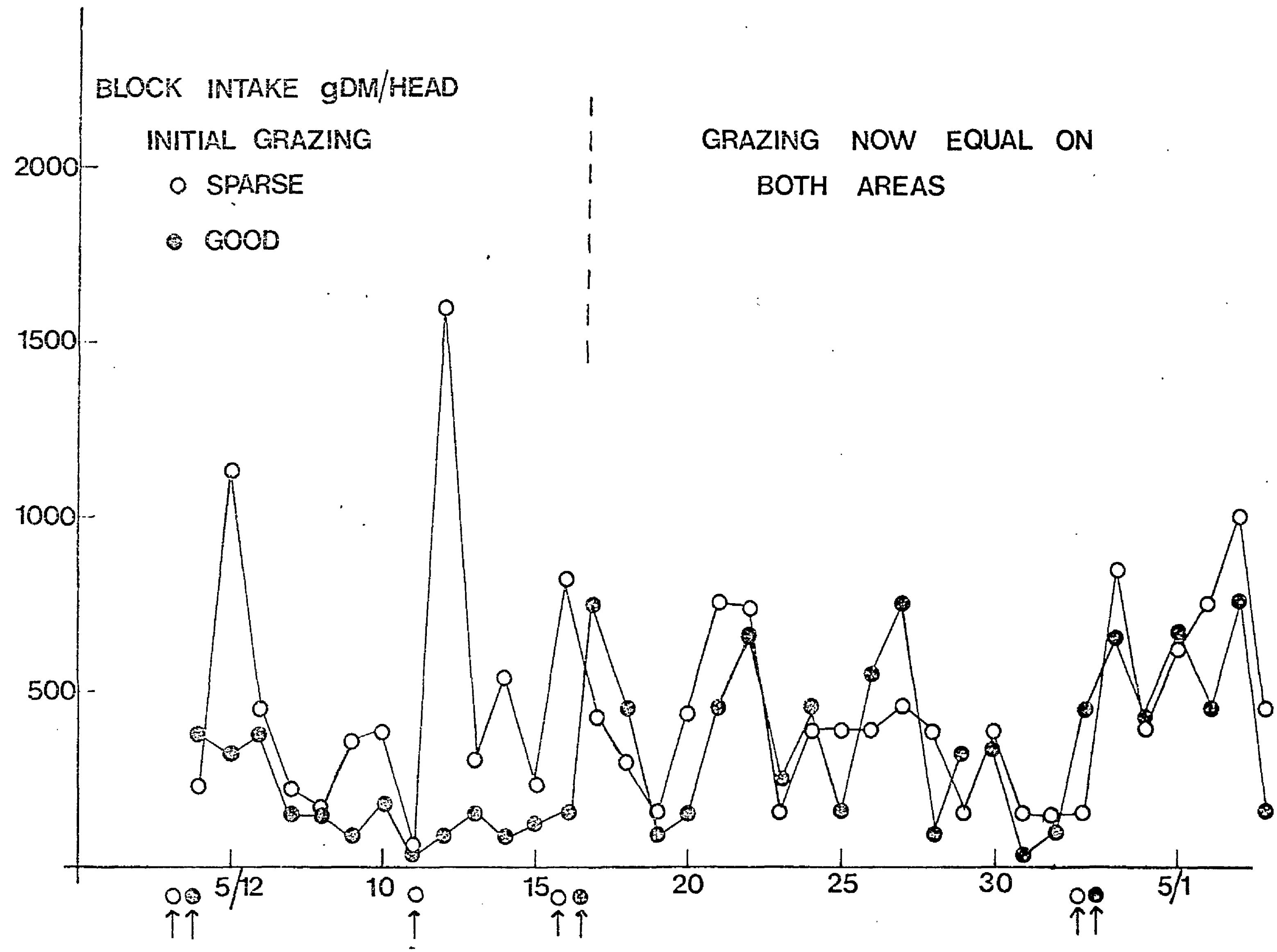
The mean daily intake of the CC feedblock was 161 $\pm$ 9 g DM/head over the whole experimental period. On two days no block was consumed. There were no significant correlations between rainfall or temperature and feedblock intake. When the chromic oxide concentration of the faeces was measured, 9 animals (33%) had values less than 10 g chromic oxide/100 kg faecal DM indicating a very low level or total absence of feedblock consumption. The mean for 27 cows sampled was 72 g chromic oxide/100 kg faecal DM (range 3 - 157) and the CV for faecal chromic oxide was 102%.

Trial II

The mean daily intakes of the W291(74) feedblocks for the two groups of cattle were 270 and 160 g DM/head. Throughout the trial there were only small amounts of rain (less than 0.1 mm) each day, except on 30 Dec and 2 Jan when about 20 mm was recorded. The mean daily temperature was in the range 2 to 10°C. There was no frost or prolonged cold periods. The intake of W291(74) feedblocks was not significantly correlated with either rainfall or mean daily temperature.

On 5 and 12 Dec there were pronounced (Fig.6) increases in feedblock intake when the new block was introduced (Field A cattle only).

Fig.6 Expt 7.2 Trial II. Changes in the mean daily W291(74) feedblock intake of 2 groups of 6 yearling Hereford X cattle with an initial difference in the herbage available during December and January.


BLOCK INTAKE gDM/HEAD
INITIAL GRAZING
SPARSE
GOOD
GRAZING NOW EQUAL ON
BOTH AREAS
2000
1500
1000
500
5/12
10
15
20
25
30
5/1

Thereafter this 'first-day' effect was noticeable for both groups of cattle. During the initial part (13 days) of the trial the intake of W291(74) was highest (416 ± 103 g DM/head) for the cattle on the bare pasture (Field A). The mean daily intake (143 ± 93 g DM/head) for the cattle on Field B was significantly lower ($P < 0{\cdot}05$). There was a tendency for W291(74) intake, to increase as grass became scarce, this was particularly noticeable from 2 to 8 Jan (Fig.6).

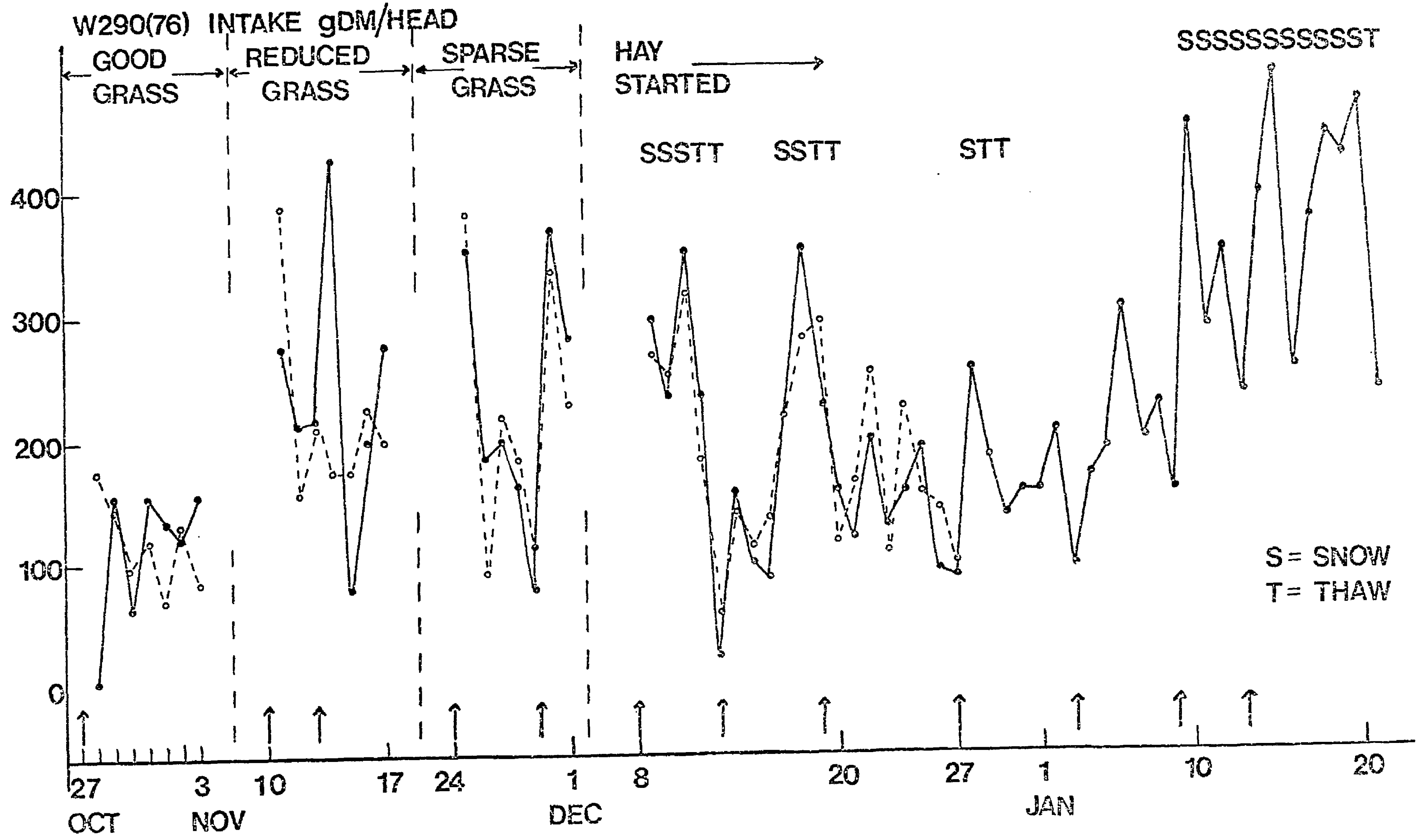
When the cattle were rectally grab sampled, 11 Dec, the mean faecal chromic oxide concentration (37 g/100 kg DM) for the cattle grazing Field A was more than twice the mean value (15 g/100 kg DM) for the cattle grazing Field B. This is consistent with the higher feedblock intake and probably lower roughage intake of the former cattle. The respective coefficients of variation for feedblock intake were 67 and 72%. One animal grazing Field B had a chromic oxide concentration of below 10 g/100 kg faecal DM.

When the cattle were rectally grab sampled on 8 Jan there was still over twice as much (122 v. 48 g chromic oxide/100 kg DM) chromic oxide in the faeces of the cattle grazing Field A than Field B. There was slightly more variation in faecal chromic oxide concentration for cattle grazing Field B (CV = 119%) than for the cattle on Field A (CV = 92%).

Trial III

The pattern of daily intake for the W290(76) feedblocks given to the cattle in Trial III is outlined in Fig.7. During the first 4 periods when blocks were given there was close similarity between absolute level of block consumed and also fluctuations in block intake between days for both groups. The increased consumption during the 24-hr period following introduction of a new block was measured on some occasions (for example 11, 25 Nov, 9 and 28 Dec) but not on others

Fig.7 Expt 7.2 Trial III. Mean daily intake of W290(76) feedblock (g DM/head/day) for 2 groups of 200 kg weaned suckler calves during winter. During the periods 3 to 9 Nov, 17 to 23 Nov and 1 to 7 Dec concentrates were given.


W290(76) INTAKE gDM/HEAD
GOOD GRASS
REDUCED GRASS
SPARSE GRASS
HAY STARTED
SSSTT
SSTT
STT
SSSSSSSSSSST
S = SNOW
T = THAW
400
300
200
100
0
27
OCT
3
NOV
10
17
24
1
DEC
8
20
27
1
JAN
10
20

(14 and 20 Dec, 3 and 10 Jan), when other factors appeared more important in determining the level of feedblock consumed, such as a rapid thaw following snow cover. The mean feedblock intakes are given in Table 19 (Section 1). There was a progressive increase in mean daily feedblock intake reflecting inversely the amount of grazing available (an increase of 130 to 290 g DM/head between periods 1 and 3). Subsequently the level of intake attained depended very much on the presence or absence of snow cover (Fig.7). The effect of snow cover could not be separated from temperature as there was a prolonged period of cold from mid December to mid January when mean daily temperatures were near or at $0^{\circ}C$.

There was a marked decrease in feedblock intake following a rapid thaw and the reappearance of grazing for the cattle. The effect of snow cover on feedblock intake was studied over the period from 8 Dec to 21 Jan when hay was given. The mean daily feedblock intake on 17 days with snow cover (413 ± 26 g DM/head) was significantly ($P < 0{\cdot}001$) greater than on 27 days with no snow cover (194 ± 14 g DM/head).

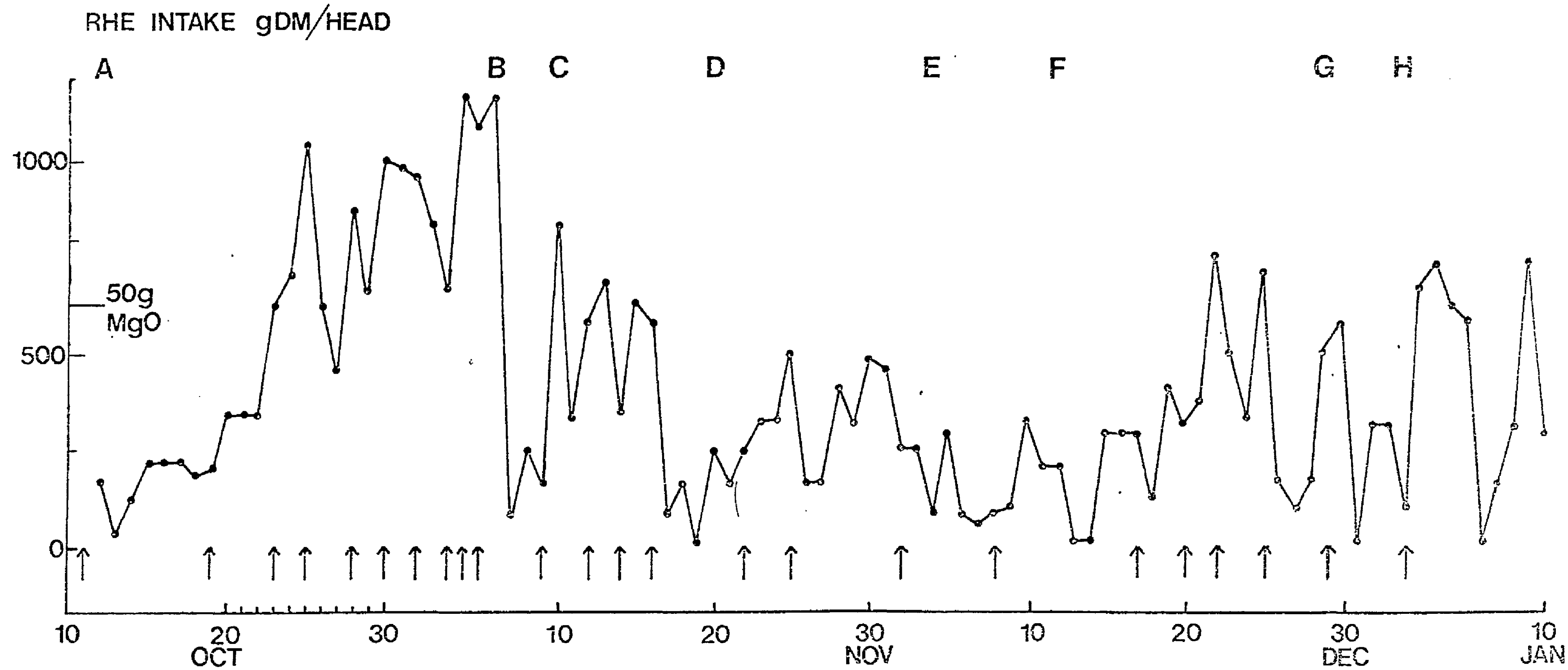
There were no significant correlations between the intake of the W290(76) and either rainfall (0 to 9·5 mm/day) or mean daily temperature (-3 to $+9^{\circ}C$) as these effects (if any) were obscured by the presence or absence of snow.

Trial IV

Throughout Trial IV the weather was generally very wet and relatively mild with only 10 days when the mean daily temperature dropped below $3^{\circ}C$.

The pattern of RHE intake over the whole trial from 12 Oct (1975) to 18 Jan (1976) is presented graphically in Fig.8. Fluctuations in absolute feedblock intake seemed to depend on the amount of grazing available and perhaps also enclosure size. From 12 Oct to 7 Nov (A to B, Fig.8) the 12 cows grazed a field of 3·2 ha. Initially the grass was very good but gradually became limiting in quantity. RHE intake

Fig.8 Expt 7.2 Trial IV. Mean daily intake of RHE feedblock (g DM/head/day) given to a group of lactating suckler cows over 90 days during winter.


RHE INTAKE gDM/HEAD
A
B
C
D
E
F
G
H
1000
500
0
50g
MgO
10
20
OCT
30
10
20
30
NOV
10
20
30
DEC
10
JAN

increased progressively from about 170 g DM/head/day to about 840 g DM/head/day by 24 Oct. When the grass was in very short supply (30 Oct), feedblock intake reached 1180 g DM/head/day and the mean daily intake over the 26-day period was 583 $\pm$ 73 g DM head. Part of the inter-day variation in feedblock intake was probably due to the tendency of some blocks to be eaten into a crescent shape, which quickly disintegrated in the bottom of the container. There was no 'first-day' effect as measured for the cuboid blocks, but it should be appreciated that the level of intake attained necessitated the introduction of a new block daily, on many days.

When the feedblocks were weighed at 4-hourly intervals throughout a 24-hr period, there did not appear to be any period when intake was either markedly greatest or very increased or decreased, but the observations may have disturbed the cattle.

On 7 Nov (B, Fig.8) the cows were transferred to another field of similar size, offering equally sparse grazing. Feedblock intake rapidly decreased to 85 to 170 g DM/head/day during the initial three days, when the cows appeared to be exploring the field. They started to consume block readily again on day 4 after changing enclosures.

On 11 Nov (C, Fig.8) the cows were transferred to a larger field of 25 ha which offered only very sparse grazing. The mean daily intakes reached about 700 g DM/head but were very low on 17 and 19 Nov. These days were characterised by frost during the night.

On 20 Nov (D, Fig.8) the cows were given access to another enclosure of 20 ha with quite good grazing. Mean daily intakes were about 350 g DM/head (17 g Mg/head) until 28 Nov (by this time grass availability was low), when there was a high wind and wet snow cover, causing the cows to shelter. The cows were now receiving 2·5 kg hay/head/day (2 Dec). On 4 Dec (E, Fig.8) two cows were found dead with signs of struggling which suggested hypomagnesaemia (a cow in the next field died of hypomagnesaemia the same day). Faecal samples (for chromic oxide) and blood samples (for magnesium) were obtained from all 14 surviving cows on 15 Dec. The mean faecal chromic oxide concentration was 23 g/100 kg DM (range 11 to 55), with a CV of 58·8%. Faecal samples from the 2 dead cows contained 11 g chromic oxide/100 kg DM, equivalent to the lowest concentrations for the surviving animals. The mean plasma magnesium concentration of all the cows was 1·43 ± 0.10 mg/100 ml, 8 cows had values between 1·5 to 2·0 mg/100 ml, 5 cows had values between 1·0 to 1·5 mg/100 ml and one cow had a verylow value of 0·58 mg/100 ml. There was no significant correlation between plasma magnesium and faecal chromic oxide concentrations.

All the cows were now (4 Dec) given 2 magnesium bullets (Pfizer Ltd.) and 850 g concentrate DM/head/day containing 50 g MgO, until 14 Dec. The overall mean RHE intake over 25 days was 234 ± 29 g DM/head/day.

On 12 Dec (F, Fig.8) a further 20 ha of grazing were made available to the cows (40 ha in total) but of very sparse grazing and the block was repositioned from near the hay feeder to 100 m distant. No block was consumed for 2 days but thereafter intake increased progressively to about 700 g DM/head/day. On 22 Dec the hay allocation was increased to 3·75 kg/day and this seemed to reduce block intake to about 160 g DM/head/day. From 29 Dec to 3 Jan (G to H, Fig.8) there were 2 very wet and then 2 very sleety days, combined with high winds, which forced the cows to shelter. In an attempt to maintain block (magnesium) intake the block was removed from its container. Consumption increased for only one day and then declined to about 80 to 160 g DM/head/day (4 to 8 g magnesium). It was noticed that the sleet, though not heavy, 'coated' the feedblock and it was not until the weather improved that block intake increased to about 700 g DM/head/day (34 g Mg). Over the 26-day period when the cows were allowed access to about 40 ha, the mean daily intake of RHE was 375 ± 51 g DM/head.

A 36-day period from 2 Dec to 7 Jan when experimental conditions were relatively constant was used to study the effect of climatic variables on feedblock intake. There were no significant correlations between feedblock intake and rainfall. The effect of mean daily temperature on block intake showed a significant ($P < 0{\cdot}05$), negative correlation ($r = 0{\cdot}42$) over a range in temperature 0 to 8°C. This relationship was expressed as a linear regression equation (Fig.9) $y = 53x + 127$ (where y = feedblock intake g DM/head/day and x = mean daily temperature °C).

Trial V

There were no significant correlations between the intake of the W291(76) feedblock and either mean temperature or rainfall over the periods studied. On 2 occasions when 'heavy' driving rain occurred together with strong winds, feedblock intake decreased to virtually zero on one day and was very low on the other.

The pattern of W291(74) intake over the experimental period is given in Fig.10. The mean daily DM intakes were 712 ± 58 and 637 ± 70 g/head, when single blocks were given with or without containers, respectively. The CV for inter-day total group intakes of block were 23·2 and 33·0%, respectively. When 4 blocks were put out, sufficient to last for about a week (23 to 29 March, 30 March to 8 April), on a single day in no containers, the mean daily DM intake of W291(76) blocks over the 16-day period was 506 ± 84 g/head. The CV for inter-day variation in block intake was 66·6%. It was noticed that the cattle preferred some individual blocks to others and once these were consumed, intake on subsequent days decreased progressively. Fig.11 shows the rate of disappearance of the individual W291(74) feedblocks and an impression of the order in which they were consumed, when given with or without containers. For example, when 4 blocks were put out over the

Fig.9 Expt 7.2 Trial IV. The effect of mean daily temperature ^{o}C on the mean daily intake of RHE feedblock (g DM/head/day) by a group of 16 suckler cows at winter grazing.

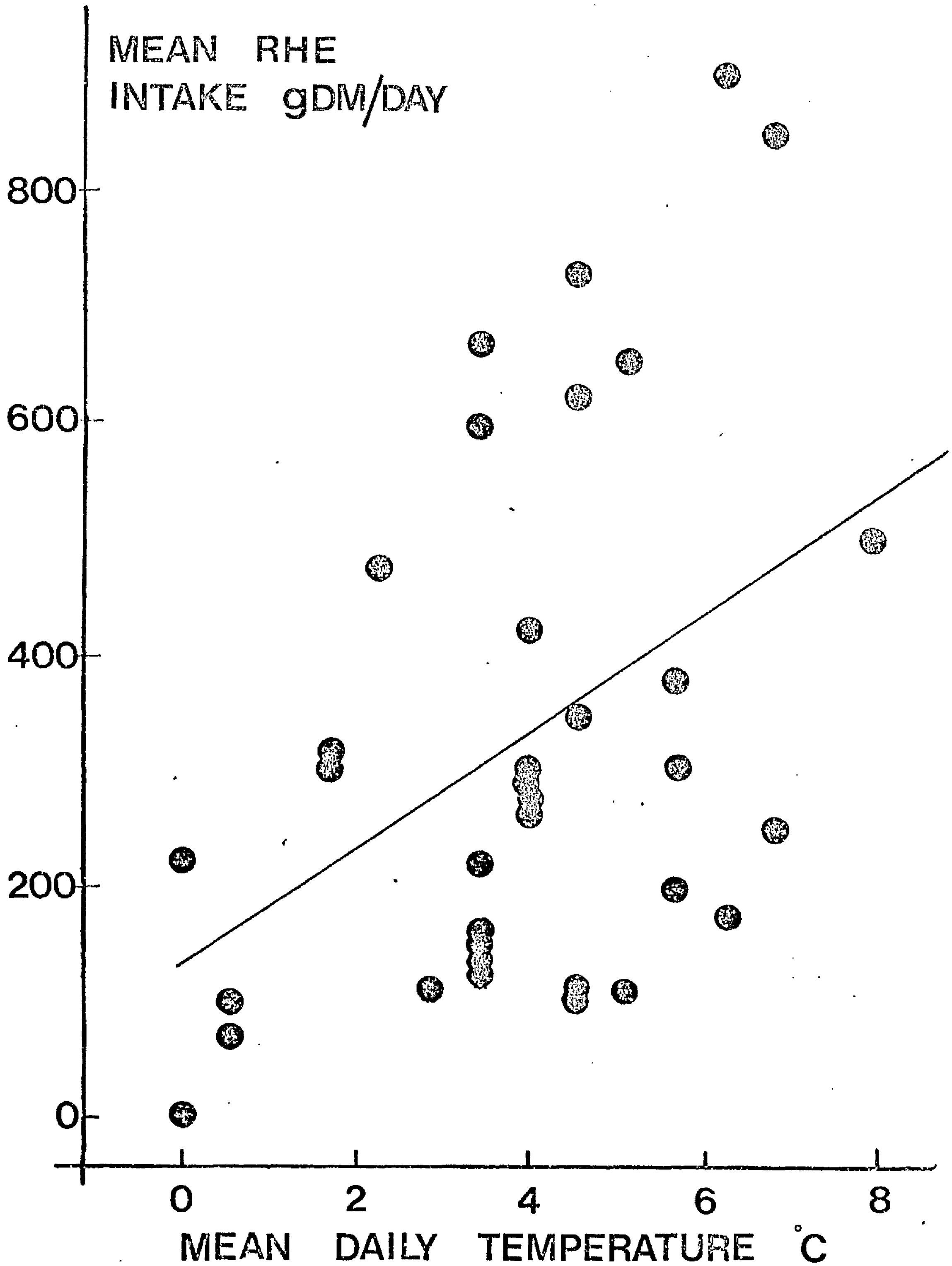
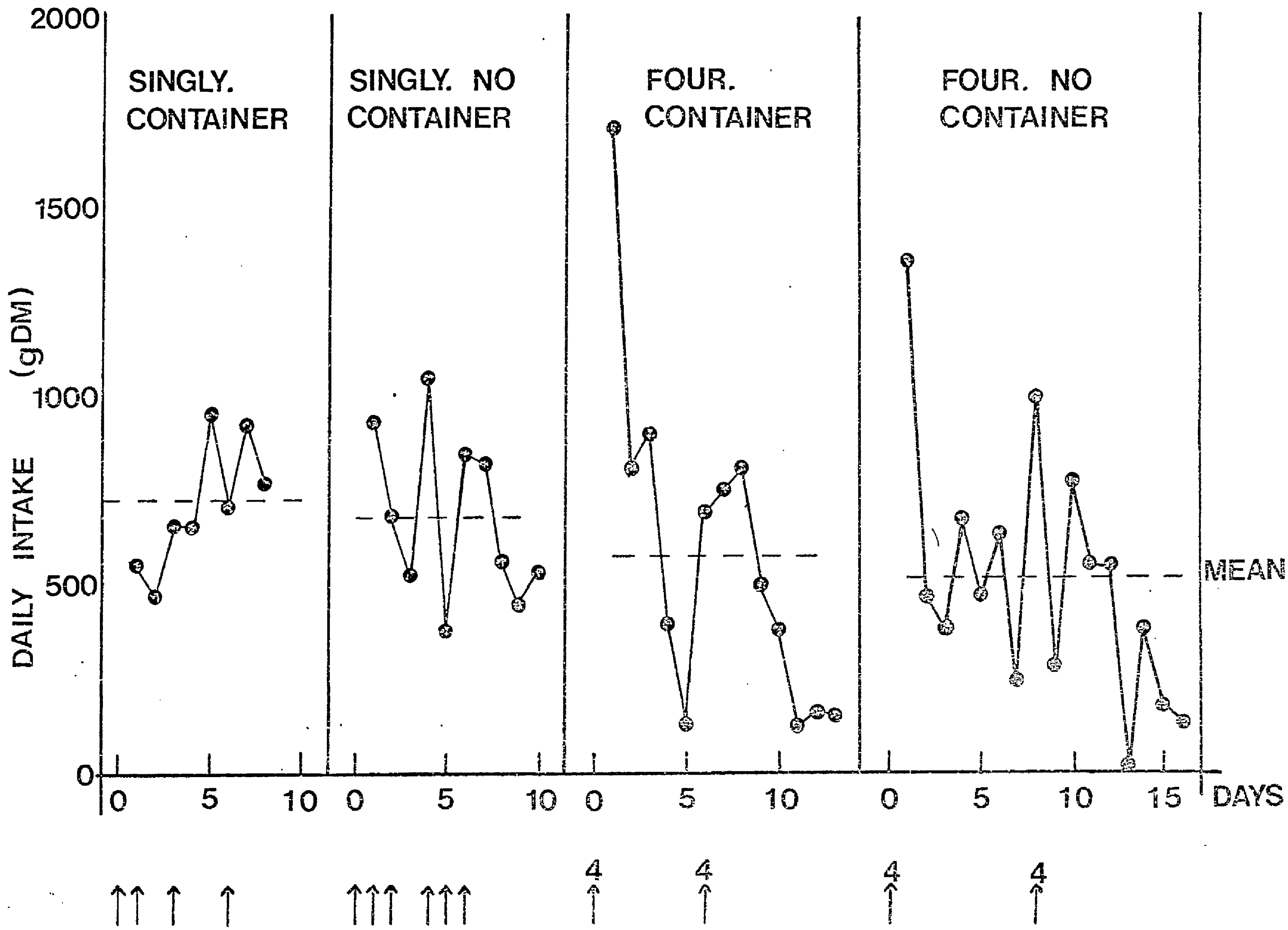
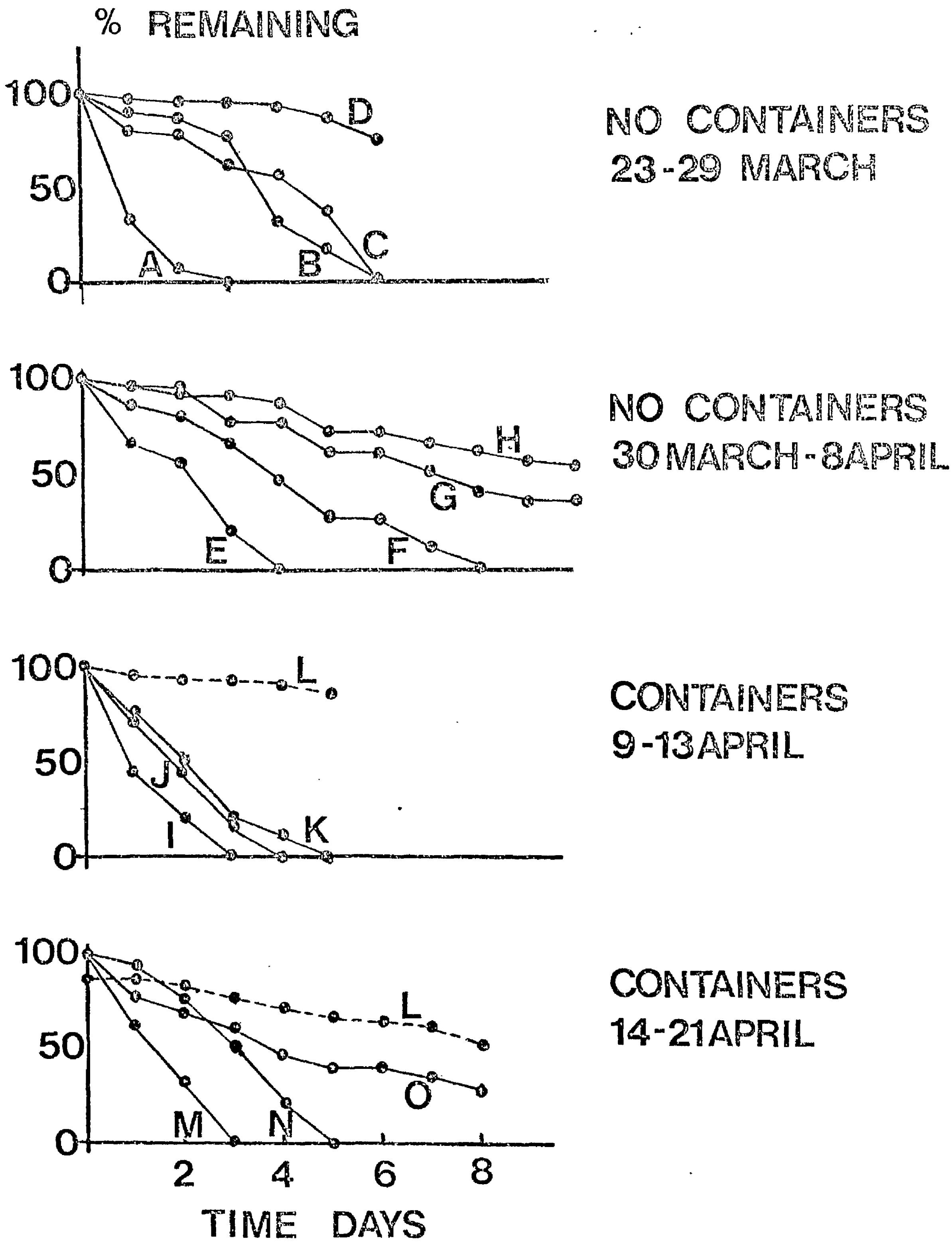

MEAN RHE
INTAKE gDM/DAY
800
600
400
200
0
0
2
4
6
8
MEAN DAILY TEMPERATURE °C

Fig.10 Expt 7.2 Trial V. The effect of giving W291(74) feedblocks either singly or four at a time on the mean daily intake (g DM/head/day) of 14 cows at winter grazing.



DAILY INTAKE (gDM)
2000
1500
1000
500
0
SINGLY. CONTAINER
SINGLY. NO CONTAINER
FOUR. CONTAINER
FOUR. NO CONTAINER
MEAN
DAYS
0
5
10
15
4

Fig.11 Expt 7.2 Trial V. Rate of disappearance of individual W291(74) feedblocks when given to a group of 14 suckler cows at winter grazing.


% REMAINING
100
50
0
A
B
C
D
NO CONTAINERS
23-29 MARCH
100
50
0
E
F
G
H
NO CONTAINERS
30 MARCH - 8 APRIL
100
50
0
I
J
K
L
CONTAINERS
9-13 APRIL
100
50
0
L
M
N
O
CONTAINERS
14-21 APRIL
2
4
6
8
TIME DAYS

period 23 to 29 March in no containers, one block was consumed within 3 days (A), 2 further blocks (B and C) were consumed within 6 days, while about 70% (14 kg) of the final block (D) was still left after 7 days. A similar pattern of block intake when cattle showed a preference for individual blocks was shown in the period 30 March to 8 April. One of the 4 blocks was totally consumed by 4 days (E) and a further block by 8 days (F). The remaining 2 blocks weighed 9·6 (H) and 6·4 kg (G) (48 and 32% uneaten, respectively) even after 10 days.

When about a weeks supply of W291(76) was put out in containers (9 to 13 April and 14 to 21 April) the mean daily intake was 566 $\pm$ 120 g DM/head with a CV for inter-day intake of 76·7%. During the first period (9 to 13 April) when 4 blocks were given on 9 April, one block was totally consumed after 3 days (I), a further block was consumed by day 4 (J) and a third block by day 5 (K). The remaining block (L) still weighed 16 kg (80% uneaten) and was left with cattle. During the second period (14 to 21 April), one block was consumed by 2 days (M), a second block was consumed totally by 4 days (N), while the remaining two blocks (including block (L), which remained unconsumed from the previous period and now weighing 9 kg) were still unconsumed even after 8 days.

Discussion

The effect of mean daily temperature on the intake of W290(74) and W291(74) feedblocks as reported by Ducker and Fraser (1975) was not found to be very important in the present studies. There may well have been an influence of mean daily temperature on feedblock intake but this was far less important in contributing to inter-day variation than other factors, principally the elevated 24-hr intake when a new block was introduced. This is consistent with the results of Expt 2.1 when a similar 'first-day' effect was recorded for the W290(74) and W291(74) feedblocks, given to groups of 16 ewes. When a larger group of ewes (30) were given the blocks outdoors, the mean intake over the initial 24-hr period was 3 to 4 times greater than the mean intake over subsequent days. This considerable variation in inter-day feedblock intake completely masked any effect of climatic variables on intake (Fig.12). The possible causes of this 'first-day' effect for the W290(74) and W291(74) feedblocks were discussed in Section 1 Part A but the main reason appeared to be the fragile exterior of these blocks, particularly the corners, which accounted for the elevated intake. This may have been exacerbated by poor storage of the blocks (in humid climates), resulting in moisture penetration and softening. A novelty interest due to the provision of clean material uncontaminated with saliva may also have contributed, but to a lesser extent.

In the experiments of Ducker and Fraser (1975) using equivalent Wintawell (1974) feedblocks, given to Dorset Horn ewes, the level of intake achieved necessitated the introduction of a new block daily and the withdrawal of a small amount of residue. Therefore, in their trials the 'first-day' effect was eliminated and not even recognised and the influence of climatic variables then became an important contributory cause, to inter-day variation in intake for the feedblocks.

A further interesting fact to emerge from the weather trials using W290(74) and W291(74) feedblocks was that the mean intake of these blocks could be increased (nearly doubled for the W290(74)) by providing two blocks instead of one. This was also intimately concerned with the greater provision of easily removed corner material and an increased surface area of block material on offer.

In all the trials where the effect of climatic variables on feedblock intake were measured, the blocks were never allowed to be consumed to exhaustion (with the exception of cattle Trial V when one weeks estimated supply of block was given on one day) and a new block was introduced in most cases when 25% of the block was still remaining. Clearly this is somewhat artificial compared to the practical situation,

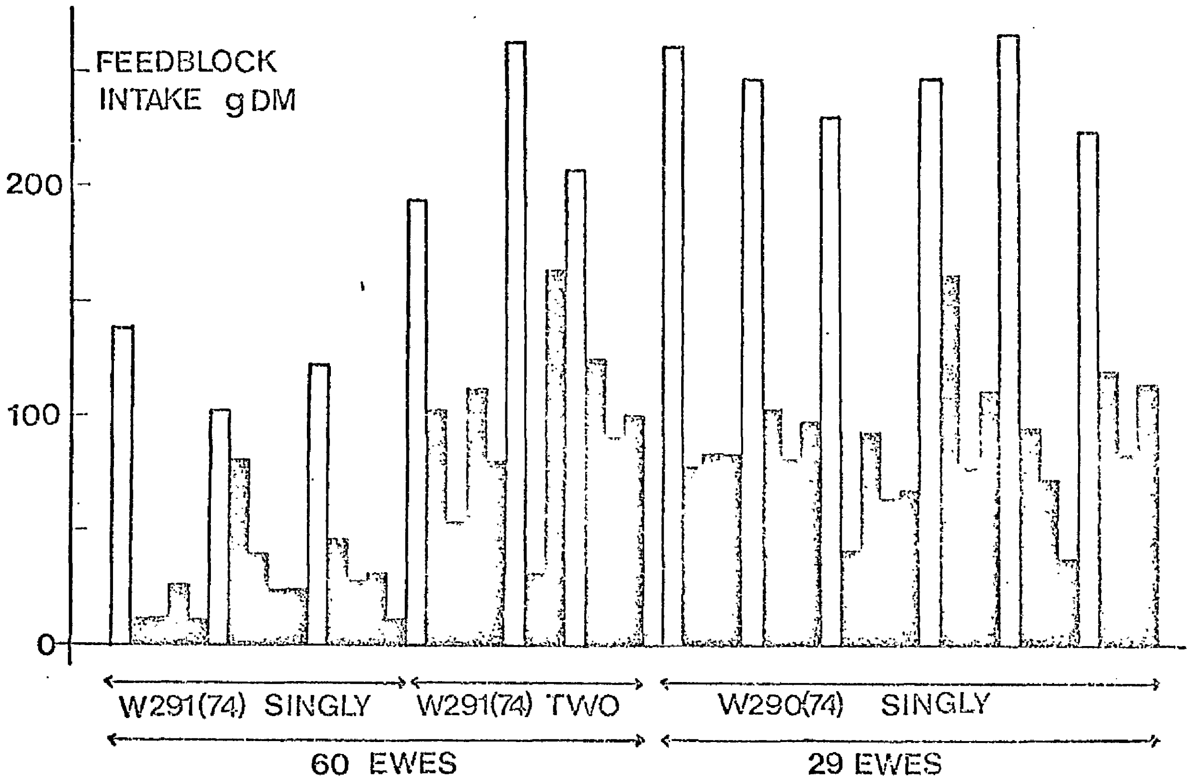


Fig.12 Expt 7.1 Inter-day variation in intake (g DM/head/day) of W291(74) (given singly or in duplicate) and W290(74) feedblocks offered to groups of 60 and 29 pregnant Greyface ewes during February and March. The unshaded area represent days when a new block was introduced.

when it is customary to put out a weeks supply of feedblocks on one day. When observations were made on the consumption of W290(74) and W291(74) to exhaustion with sheep, there was a tendency for the final 25% of each block to remain uneaten for a long period (up to 4 to 5 days). Consequently, although in theory the block was on ad libitum offer it became unattractive to the stock (perhaps by soiling), quite independently from any climatic influence. In the case of the W290(74) and W291(74) it is very likely that this would result in a highly irregular pattern of feedblock intake, with perhaps 50% of the weeks allowance consumed within 24 hours and a progressive reduction in feedblock intake over subsequent days. The consequences of this, particularly when feedblocks are relied upon to supply a significant part of the total nutrient intake or, for example magnesium as a prophylactic against hypomagnesaemia would be extremely serious. On some days the majority of stock probably might not consume any feedblock, and on others a wasteful overconsumption would occur.

In Expt 7.2, Trial V, beef-type cows were given an estimated 7 days supply of W291(76) feedblocks on a single day (with or without containers), or blocks singly throughout the week (also with or without containers), with the blocks replaced when less than the previous days total consumption remained. When the weeks supply of blocks was given on a single day, compared to giving blocks singly throughout 7 days, the coefficient of variation for block intake between days was increased about 3 and 2 fold for blocks given with and without containers, respectively. There was also a noticeable tendency for the cows to prefer individual blocks when given a choice between several. Some blocks were refused or consumed only very slowly, even when the more attractive blocks had been totally consumed. Most of the block material on offer was consumed (15 to 35% of the total supply) during the 24-hr period following introduction. The net effect was to give an exponential and non-uniform pattern of feedblock intake throughout the 7-day period and a slightly lower level of intake, compared to giving blocks singly, because of the unacceptability of some individual blocks, which remained unconsumed even after 7 to 10 days.

The preference of the cows to consume certain blocks and reject others probably reflected differences in block hardness. The most useful indication of block hardness for the W291(76) feedblock was block length. The harder the block the shorter its length and vice versa. Very hard blocks measured 31 to 32 cm in length, whilst soft blocks were 35 to 37 cms, although their weights were identical. It was noticed that the blocks remaining uneaten after several days, were short in length (physically hard) and those rapidly consumed were longer and physically softer.

Whether this difference in block length/hardness was a quality control aspect peculiar to this batch of blocks or reflected normal differences in blocks of this type could not be ascertained. Nevertheless it is clearly an undesirable feature which may add to the already imprecise nature of feedblock intake. There were accordingly differences in rate of consumption within the life of a particular block (the corner material is relatively easy to consume) and also between blocks, due to variations in physical hardness. The particular containers used in Trial V served mainly to keep the blocks clean and gave a small (6 and 12% respectively when single blocks or 4 blocks were made available) but not significant increase in intake compared to no containers.

The effect of climatic variables on the intake of W290(74) W291(74), W291(76) and other rectangular-cuboid feedblocks, although important under some circumstances, appears to be of much less significance than the fluctuations in mean group intake due to the number of blocks available, variations in block hardness, whether protection is afforded to the corners by a container and how frequently new blocks are introduced. Therefore the inter-day variation in intake and also the absolute level of intake attained, depends principally on the management routine adopted by the stockfeeder. If Ducker and Fraser (1975) had not removed the block residues each day but had still introduced a new feedblock each day, a situation would eventually have been reached when sufficient block material was on offer, to exceed the previous days consumption without the introduction of a new feedblock. The effect of weather on feedblock intake would then be secondary to the amount and character (e.g. ± contamination) of the block residues present and manipulations made by the stockfeeder would mainly dictate inter-day variation in intake.

The supplement RS (for sheep Expt 7.1; Table 22) and RHE (for cattle Expt 7.2; Trial IV) feedblocks did not show any consistent 'first-day' effect, on days when a new block was introduced. Therefore the degree of inter-day variation due to how the blocks were given, was much less pronounced than for the W290(74) and W291(74) feedblocks. Climatic variables and other factors such as herbage/roughage availability, now became perhaps the most important determinates of inter-day intake variation. The intake of both the RS and RHE feedblock (cattle only) was significantly lower when the mean daily temperature approached 0°C. In one study (Table 22) when the RS feedblock was given to pregnant ewes in February 1976, the mean daily intake on days when mean temperature was below 2°C was only 50% of the mean intake on days when mean temperature exceeded 2°C. The intake of the RS feedblock was also significantly influenced by rainfall under the circumstances studied. The intake was greater on rainy days (>1 mm rainfall), particularly over the temperature range 3 to 10°C. It may also have been influenced at higher temperatures but these did not occur during the periods of study. Below 3°C, temperature appeared to be the most important climatic influence on feedblock intake. Perhaps a more sensitive climatic parameter affecting feedblock intake would be relative humidity, which was not recorded in experiments in this Section.

On very wet windy days it was noticed that the intake RHE by cattle (Expt 7.2; Trial IV) decreased due to the animals seeking shelter. In such weather conditions the siting of the blocks is of utmost importance because it is at these times that animals, particularly suckler cows, are predisposed climatically to hypomagnesaemic tetany. In Trial IV the deaths of two suckler cows coincided with a period of heavy driving rain when total reliance for supplementary magnesium was placed on the feedblock. On other occasions it was almost impossible to maintain feedblock intake, when the weather was exceptionally cold or heavy driving rain occurred, at a level where about a mean 60 g MgO/head/day was being consumed.

The reasons for a decrease in feedblock intake during cold, dry weather conditions are perhaps less obvious than under conditions of heavy driving rain. There are several possible explanations. Firstly, a physical change in the block might possibly occur, leading to a harder external surface. This is perhaps very unlikely because all the blocks used, contained appreciable inclusions of salt which would prevent the block from 'freezing.' Also, the reduction in intake occurred even when the mean daily temperature was $2^{o}C$, although at times during the 24 hr period the temperature may have been below $0^{o}C$. The most likely explanation for this reduced intake is probably intimately concerned with the water consumption of the stock. The intake of any salt-containing supplement depends almost certainly on water availability, salinity and intake. It is well known that ruminants drink less water on cold, dry days when there is also less moisture in the herbage, therefore a decrease in water intake would probably result in a concomitant reduction in salt/block intake. This is consistent with the observation that even housed sheep consume less feedblock on cold, frosty days.

When the temperature increases and/or rain occurs, the intake of feedblocks usually increases (unless another overriding constraint is operating). This may be directly attributable to the stock drinking more water on dry, warm days and thus being able to excrete a greater quantity of salt from the feedblocks. On warm, rainy days a second, indirect mechanism encouraging feedblock consumption may be in operation. When stock are allowed grazing, it is possible that after each visit to the feedblock the unpalatable taste of the block material (salt or otherwise) is diluted by the moisture contained in a few mouthfuls of wet herbage and thus block consumption is enhanced.

On very hot, dry days (mean daily temperature $> 20^{\circ}C$) it was noticed that the intake of feedblocks was drastically reduced. This may reflect a change in behaviour of the stock in that they seek shade for a large proportion of the day and spend less time in eating block. It may also reflect a change in physical nature of the feedblock so that it develops a hard, 'baked' exterior. A third contributory cause is a possible reduction in water availability either directly or indirectly to the stock.

The intake of the CC feedblock was not significantly influenced by the climatic variables examined, under the conditions described in Expt 7.2, Trial I. There was a tendency for the intake over the initial 24-hr period to be higher than on subsequent days but this trend was inconsistent and considerably less pronounced than for the W290(74) and W291(74) feedblocks. Although cuboid in shape the CC feedblock had bevelled corners and was more generally robust than the Wintawell(74) blocks. There was considerable inter-day variation in intake of the CC feedblock and on two days no block material was consumed. This coincided with the cattle being allowed access to an extra enclosure of approximately 6 ha. Previously they had been confined in a small area (0.25 ha) of rock strewn ground almost completely devoid of grass.

Although in theory outwintered, the cattle given CC block were in a situation effectively similar to cattle wintered in part-open yards. No single contributory cause could be ascribed to the inter-day variation in total group intake of block and it is likely that a combination of factors including quantity of silage available, weather, 'age' of the block, as well as changes in the area allowed, influenced block intake.

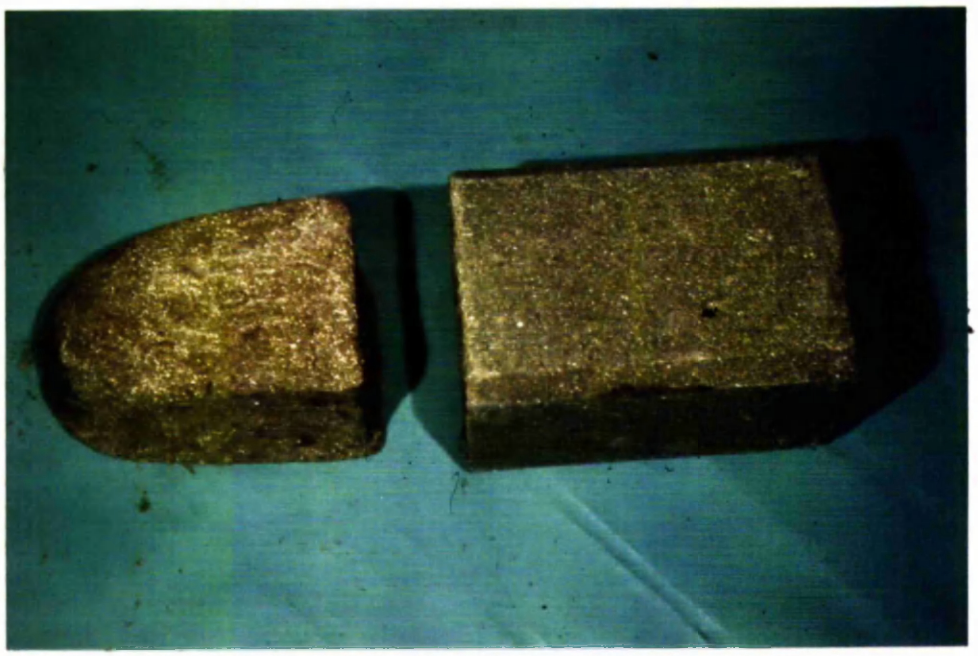
The effect of complete snow cover, preventing access to grazing, was to enhance feedblock consumption in nearly every situation. This was observed to be the case for all the feedblocks examined, with both cattle and sheep. The principal reason for this increase in intake is likely to result from hunger in the stock, due to absence of nutrients in any form other than from the block. The animals appeared to spend far more time at the block on days when snow cover existed, unless roughage was made available such as hay. Nevertheless, even when hay was given over a prolonged period (Expt 7.2; Trial III) block intake was significantly higher on days where snow cover existed.

Undoubtedly climatic variables are a contributory factor influencing both inter-day variation and absolute level of feedblock intake in any situation but their relative importance may often be overshadowed by other criteria. These include management factors such as the number of feedblocks available, when new blocks are introduced, the shape of the blocks and whether they are placed in containers.

1. Centre, W290(74) feedblock weighing 22.7 kg. Left, partly consumed W290(74) feedblock weighing 10 kg and right, a similar block weighing 16.0 kg. Both partly consumed blocks show a 'battlement' type of appearance due to the presence of hard, 'lime spots' which arise from uneven mixing of the ingredients.

2. Right, W291(76) feedblock (20 kg) and left, a partly consumed W291(76) feedblock (10.5 kg) showing a non uniform pattern of consumption. The 'bullet' shape arises from uneven compression being applied to the block, creating a soft and hard end to the block. The soft end is eaten in preference to the hard end.

3. W290(76) feedblocks intact and after 24, 48 and 72 hours consumption by a group of 30 sheep. The block residues weigh 12.0, 5.5 and 2.0 kg respectively from left to right.



Rumevite standard feedblock (22.7 kg) and purpose-built container. Right, partly consumed RS feedblock weighing 15 kg.

Top left, CSE feedblock (20 kg) and bottom left partly consumed CSE feedblock (9 kg) showing typical shape when consumed without a container. Top right, purpose built plastic container for Colborn blocks. Bottom right, typical shape of a CSE feedblock (15 kg) after consumption by sheep from a container.

B The effect on containers on the intakes of feedblocks

The advice given to the stockfeeder by the feedblock manufacturers on whether a container should be employed with their products is somewhat arbitary and perhaps speculative. Of the blocks used in this thesis the RS, RHE, CSE and CC feedblocks were usually recommended to be given in containers. Containers may be purpose-designed or improvised form old tyres, wooden boxes, oil drums etc. The W290(74), W291(74), W290(76) and W291(76) feedblocks were recommended to be given without a container in most circumstances. It is not usually appreciated that a container can affect the intake of any particular block in both a positive as well as a negative manner. Containers are principally employed to protect the weaker parts of a block such as the edges and corners and also reduce the surface area available to the stock. They may also alter the method of prehension of block material by encouraging licking rather than biting. Accordingly in many situations containers are intended to restrict block intake. Containers may increase feedblock intake by providing a stable base for the block and thus afford animals a greater opportunity to exert prehensible force, particularly when only a small mobile proportion of the block is remaining. Containers also probably encourage feedblock intake by keeping the block free from mud and faeces. It was noticed that with cattle in particular, that contamination of a block at any stage with faeces is a potent inhibitor of consumption and this occurred much less frequently when the block was in a container.

In several small trials (not described in detail here) when the same feedblocks (W290(76)) were given in containers of various descriptions or without containers,there were no significant differences in daily intake, which were 196 $\pm$ 57, 219 $\pm$ 31 and 191 $\pm$ 32 g DM/head when the block was given in a solid based container, a perforated based container and without a container, respectively. The feedblocks were given to a group of 10 mature Dorset Horn ewes and both containers were 15 cm deep,which protected only a limited portion of the edges. The perforations in the base of the container were designed to allow water to drain away but due to the low rainfall over the trial their efficiency could not be assessed. It was observed that when containers were employed with cuboid-shaped feedblocks,which allowed only the top surface of the block accessible to the stock (CSE feedblock-containers especially), feedblock consumption was decreased. When the wheel-shaped RS and RHE feedblocks were given in their purpose-built tins to sheep no consistent effect on pattern or level of intake was recorded, which differed from the intake when no containers were used. With cattle however, intake accelerated when a container was used over the last approximately 25% of the feedblock life,due to the animals being able to bite at the block against a stable base. It also was noticed that during periods of high rainfall the drainage holes in the tin container became blocked and the base of the block became very soft and water accumulated in the container.

In the final analysis it is usually the stockfeeder who determines the type of container to be used,if one is employed at all. Undoubtedly containers can and do alter the level of feedblock consumed in any situation. They also influence the inter-day variation in feedblock intake by reducing the 'first-day' effect and the consequent overall intake for the cuboid-shaped feedblocks. However in some instances they may encourage feedblock intake particularly for the wheel-shaped feedblocks with cattle. Therefore the influence containers exert over feedblock consumption in any situation is highly variable and depends on the type and shape of both feedblock and container. One possible nutritional application for containers with the cuboid-shaped feedblocks is to initially commence giving feedblocks in containers and then as nutritional requirements increase (for example during the last 4 weeks of pregnancy in the ewe) the blocks can be removed from the containers and intake should be increased.

C The effect of quality and quantity of other dietary components on the intakes of feedblocks

The claim that ruminants given feedblocks will regulate their intakes according to both the qualitative and quantitative nature of the other dietary components is examined in considerable detail in Section 3. However it is appropriate here to mention some of the observations gained from giving feedblocks to stock under a variety of circumstances, where changes in other dietary components have been made.

The provision of alternative nutrients in a more palatable form such as spring or abundant other clean grazing, good hay or concentrates, usually effects a reduction or complete cessation of feedblock consumption. This was particularly evident where cattle (suckler cows) had been consuming appreciable quantities (Expt 11.1) of the RS feedblock (500 g DM/head), under conditions of winter management (indoors), but upon turn-out to lush spring pasture no interest was shown in the same block whatsoever, for over about 30 days. Eventually the cows started to consume the blocks, but only after the grass became scarce and the areas of fouled and unacceptable grazing increased. A similar observation was made a year later, when the same cows were turned out and given access to an experimental CC feedblock (Expt 11.2). The previously high intakes (>500 g/head), when the cows were housed, were not recorded under grazing conditions until mid-June, when herbage availability declined, although a low mean level of intake was maintained during the immediate post turn-out period.

Further observations (e.g. Expt 7.2; Trial III) which suggest that ruminants will consume nearly all other foods in preference to blocks are firstly that after a period of snow cover (increased feedblock intake) when grazing becomes accessible to the stock again feedblock intakes decrease. Secondly, the provision of swedes to pregnant ewes in late February (Expt. 7.1) reduced the mean intake of RS from 82 ± 11 to 38 ± 8 g/head. The difference was significant ($P < 0.01$). The ewes were receiving RS feedblock plus access to bare winter pastures.

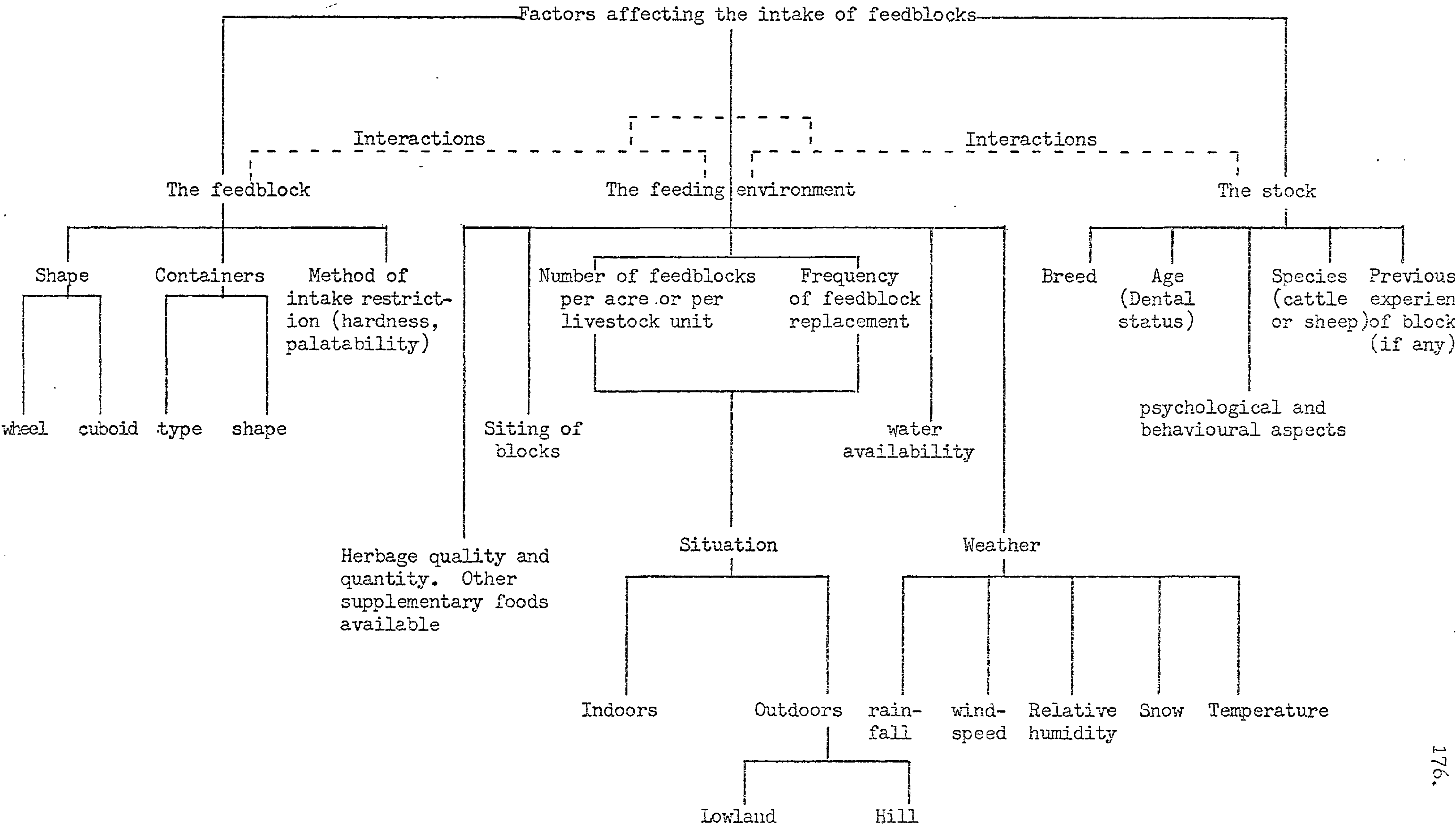
General Discussion

The results and observations of Section 2 illustrated the imprecise nutrition of providing nutrients in block form to stock. It is only when the feedblocks are actually given to the animals that level of intake can be assessed. Within any mean group intake of block there were considerable fluctuations in intake between days and over extended periods. Therefore the system of giving nutrients in block form is imprecise in two ways; firstly, because there is little control over the absolute intake attained and secondly, the absolute intake is liable to fluctuate markedly in response to a whole variety of factors. When the results of Section 1 (individual variation in feedblock intakes) and this Section are considered together, it is perhaps somewhat optimistic to expect feedblocks to effectively act as carriers of special therapeutic ingredients, such as anthelmintics, warble dressings or even magnesium compounds, as prophylactics against hypomagnesaemia. The latter case is examined in detail in Section 3.

The factors which can affect and contribute to the intake of a feedblock in any situation are outlined diagrammatically in Fig.13. There may well be several other factors which are not shown that may be important in some situations but in general the factors affecting feedblock intake can be divided into three categories. These being the feedblock per se, the stock and the environment affecting both. The diagram (Fig.13) does not attempt to illustrate the vast number of interactions between the various factors. For example block hardness and dental status, frequency of feedblock replacement and shape of block ('first-day' effect with cuboid blocks), animal species and type of container etc. Most of these interactions have been discussed in detail earlier in this Section. In any given situation it is doubtful if a single environmental factor is ever solely responsible for level of feedblock intake attained. It is also unlikely that the factor contributing most significantly to intake level is even remotely constant from situation to situation.

In theory, animals given feedblocks can themselves determine the quantity of nutrients taken from the block. In practice, numerous factors modulate the actual amounts taken, by placing constraints upon the maximum intake in a given situation. Some feedblock manufacturers claim that despite these constraints, individual animals given access to feedblocks can regulate their intakes according to nutritional requirements, both qualitatively and quantitatively and thereby alleviate any dietary imbalances. This stimulated the detailed investigations carried out in Section 3 into whether physiological factors, such as productive state (pregnancy or lactation) also affected the individual feedblock intake attained in a given situation. Alternatively, was it still possible for a metabolic constraint on feedblock intake to operate within the limits defined by the considerable number of other potential constraints enumerated in Section 2.

Fig.13. Diagrammatic representation of the potential factors affecting feedblock intake in any situation



SECTION 3

THE VOLUNTARY INTAKE OF FEEDBLOCKS IN RELATION TO THE NUTRIENT REQUIREMENTS OF RUMINANTS

Introduction

One claimed advantage (Weir and Torrell, 1953) for the 'self-feed' system of giving nutrients, is that the animals themselves have the opportunity to determine the quantity of material consumed. The results of Section 2 indicated that this is not strictly correct for feedblocks. The intake attained in a given situation may be influenced by a wide variety of factors, which can be categorised as those inherent in either the animal, or in the block and other external factors influencing both feedblocks and animals to a considerable extent. In some circumstances these external factors such as climatic variables, quantity of herbage available and size of enclosure may be the principal determinants of feedblock intake. Therefore the statement that the animals themselves have the opportunity to determine the quantity of feedblock consumed should be qualified to the extent that this can only occur within the range of intakes where other constraints are not operating, or are not yet sufficiently severe to influence the motivation of the animal to consume feedblock. There is a much narrower range of intakes before these constraints apply for the supplement-type feedblocks than for the substitute-type blocks. The situation is dynamic for both block types in that the limits of these intake ranges are continually changing in response to changes in the external factors (weather, herbage availability, enclosure size etc.) and animal factors including behavioural patterns of the group, the dental and perhaps even the physiological status of the animal.

Several feedblock manufacturers promote the claim that in any situation feedblocks are effectively self-regulating, for example one organisation states that the formulation and manufacturing processes ensure that the intake of their blocks will be regulated according to the animal's body weight and the digestibility and availability of roughages and grass. What is exactly meant by self-regulating is not clearly defined but the results of Section 1 (Expts 2.1, 3.1, 3.2, 3.3) did not support the claim that live weight was an important contributory factor to individual variation in feedblock intake. Herbage availability did appear (Section 2) to be an important factor influencing feedblock intake in some situations. For example the intake of RS feedblock was negligible for suckler cows on lush spring pastures. Feedblock intakes gradually increased in June and July, as herbage availability declined. The pattern of feedblock intake also tended to coincide with changes in digestibility of the grazing, as well as herbage availability (low feedblock intake in April and May, high herbage digestibility; lower herbage digestibility in June and July; increased feedblock intake). Outwintered cattle and sheep gradually 'weaned' themselves off feedblocks as herbage growth occurred in the spring, but again the exact reasons for this reduction and eventual cessation of feedblock consumption were confounded by the concomitant increase in herbage digestibility with herbage availability.

One of the objectives of Section 3 (Part A) was to investigate changes in feedblock intake in response to changes in diet in both qualitative (digestibility) and quantitative (availability) terms. A regulation of feedblock intake according to the qualitative nature of the diet would seem a reasonable supposition in the extreme sense because when offered a choice, animals invariably select against the unpalatable feedblocks, if alternative more palatable foods are freely available. However the question whether a more subtle quantitative regulation of feedblock intake can occur within the intake range for a particular block and feeding environment has not been examined. If such a regulatory mechanism did in fact operate for feedblocks it would have wide-spread implications for animal husbandry. For example one of the problems facing the shepherd is at what level to give supplementary nutrients in troughs when the flock is expected to contain non-pregnant, and single and multi-gravid ewes. If the nutrient allocation is set according to the requirements of twin-bearing ewes, a wasteful over allocation is offered and vice-versa. In practice it is doubtful if this dilema is of much consequence because of the considerable variation in intake for trough given nutrients, as measured in Expts 2.3, 3.1 and 3.2.

When ewes in late pregnancy are given 'hand-fed' nutrients from troughs, it is unlikely that individual consumption bears any relation whatsoever to their requirements and this system of giving nutrients is always likely to be imprecise. However it might be possible for ewes to correct an energy deficit if feedblocks as well as 'hand-fed' nutrients are given. One possible application of this would be to allocate supplementary nutrients to a flock, with a lambing percentage 150 to 200 on the basis of all ewes carrying single lambs. Any multi-gravid ewe or undernourished single-bearing animal might then be able to make good its energy deficit from the block.

Foot, Russel, Maxwell and Morris (1974) reported that when nutrients were given to a group of ewes of mixed age group the 2-year old animals (gimmers) were at no disadvantage compared to their older counterparts, in terms of nutrients consumed. However, a proportion of the multi-gravid ewes were penalised nutritionally in the competitive situation irrespective of age.

In Section 1, the individual variation in intake by sheep given feedblocks (Expts 2.1, 3.1, 3.2 and 3.3) was invariably more than when equivalent amounts of DM were consumed from feedblocks. The sheep used in all these experiments were in the early stages (first 110 days) of pregnancy and therefore their nutrient requirements were unlikely to be much in excess of the non-pregnant state. Also at no time were they under any pronounced nutritional stress. It would be important to establish if animals suffering nutritional stress, especially in terms of energy, are able to consume nutrients from feedblocks according to their nutritional needs. A situation could possibly arise where animals motivated by hunger were prepared to spend more time at the block each day and raise their tolerance to unpalatable feedblock material, for example by drinking more water. Alternatively, it may be that in special circumstances such as late pregnancy and lactation the constraints on feedblock intake inherent in the block per se and the environment can be overcome due to adaptation by the animals under nutritional stress.

One of the main objectives of Section 3 (Part B) was to discover whether physiological factors were the principal determinants of individual feedblock intake, when nutrient requirements (particularly energy) were high and alternative sources of nutrients limited; as opposed to the feedblock palatability and other factors unrelated to the physiological and nutritional state of the animal. This took the form of two experiments using ewes in the last 6 weeks of pregnancy.

It appears to be a popular belief that ruminants have the ability to select, among the materials available to them, those which contain specific nutrients in which they may be deficient. The feedblock manufacturers and the manufacturers of free access minerals have done much to encourage and foster this belief. For example it is inferred that those animals having the greatest demand for calcium, phosphorus or magnesium will consume supplements containing these elements accordingly. The published literature on this topic will be reviewed later in this section but in general, taste rather than need appears to be the major determinant of consumption. Most feedblocks usually contain an inclusion of magnesium (usually magnesium oxide). In some cases special formulations are available for use at times when hypomagnesaemic tetany is likely to occur. Perhaps the most frequent period when clinical tetany occurs is in the spring. It is claimed that animals will consume sufficient magnesium-containing feedblock to prove effective against 'staggers,' which is contrary to the observations in Section 2 and also inconsistent with the claim that feedblock intakes will be regulated according to herbage availability and digestibility. Both herbage availability and digestibility are high in spring. Therefore a contradiction in terms is being made; feedblock intakes are stated to be very low or negligible in spring, yet it is claimed they will provide sufficient supplementary magnesium, to prove effective against hypomagnesaemic tetany. Also the individual variation in feedblock intake measured in Section 1 and the variation in total group intake between days measured in Section 2, indicate that it is somewhat optimistic to expect feedblocks to be effective carriers of magnesium compounds.

Section 3 (Part C) was concerned also with an evaluation of feedblocks as carriers of magnesium and whether ruminants consume feedblocks according to taste rather than need.

A An investigation into the ability of sheep to regulate feedblock intake according to the quality and quantity of accompanying foods

In Section 2 reference was made to the preference of ruminants to consume virtually any more palatable foodstuff rather than feedblocks. It was also shown that there were numerous possible factors which could modulate the intake of feedblock in any given situation. Amongst these were the quantity and perhaps the quality of accompanying foodstuffs. A sometimes claimed advantage for the use of 'self-help' systems such as feedblocks is that animals will regulate their intakes according to dietary need rather than taste.

In Part A of this section the effect of altering either the quality, quantity or both of nutrients not derived from the feedblock on feedblock intake was examined.

Expt 8.1. The effect of variations in amount of nitrogen (urea or vegetable protein) in the basal diet on the intake of various feedblocks

Materials and Methods

Eighteen, non-lactating, non-pregnant, Dorset Horn ewes were divided into 2 groups (C and D) each of 9 animals and housed in small pens. The ewes received a daily allocation of approximately 750 g DM/head of distillery siftings plus 215 g DM/head of sugar beet pulp nuts, containing either no urea SBP (group C) or SBPU (320 g CP/kg of which 220 g CP/kg was derived from an about 8% inclusion of urea) given to group D ewes. In addition, both groups of ewes were given the following feedblocks for successive periods of about 7 days.

1. CSE (146 g NaCl, 26 g urea/kg DM).
2. W290(76) (58 g NaCl, 51 g urea/kg DM).
3. RHE (123 g NaCl, 30 g urea/kg DM).

4. W291(76) (32 g NaCl, 50 g urea/kg DM).

The total group intake of feedblock was monitored by daily weighing. The allocations of sugar-beet pulp nuts were then discontinued and a similar quantity of either barley pellets (B, 90 g CP/kg) (group C) or barley-vegetable protein pellets (BV, 260 g CP/kg) (group D) substituted. The sheep were then given CSE (5) and W290(76) (6) feedblocks for further weekly periods. Finally the sheep received W290(76) feedblocks plus their respective allocations of either SBP or SBPU for a further period (7).

Results

The mean daily intakes of feedblock DM, salt and urea are given in Table 23 for groups C and D. The mean daily intake of the substitute-type CSE feedblock was 78% higher (period a) for group D ewes given the SBP alone than SBPU. This difference was significant ($P < 0.005$). Similarly, the intake of the substitute-type W290(76) feedblock was 110 and 89% higher for group D ewes given SBP (periods b and g respectively) than group C ewes receiving SBPU. The differences were highly significant ($P < 0.001$). There were no significant differences in the intakes of the above blocks, when either barley (B) or barley-vegetable protein (BV) pellets were given to the two groups.

The intake of W290(76) by group D ewes given SBP (1382 and 1048 g/head for periods 2 and 7 respectively) was significantly ($P < 0.001$ and $P < 0.05$) greater than when the ewes received barley pellets (838 g/head). Group D ewes however consumed 29% less CSE feedblock when given SBP (684 g/head), compared to the intake when barley was given, 838 g/head . The difference was not statistically significant.

There were no differences in mean daily feedblock intakes of either RHE or W291(76) feedblocks, irrespective of whether SBP or SBPU was given to the sheep. The levels of intake attained on these blocks were considerably below the intakes for W290(76) in all periods and CSE, except when SBPU was given (period 1) to group C ewes.

The highest intakes of salt were recorded for group D ewes during periods (1) and (2) (99 and 80 g/head respectively), when the CSE and W290(76) feedblocks were given. The lowest salt intakes occurred during period (4) (11 or 12 g/head), when the ewes received the W291(76) feedblock.

Table 23 Expt 8.1. The effect of increasing nitrogen intake by urea or vegetable protein from extraneous sources on the mean intake (±SE) of various feedblocks (9 ewes/group)

Period	Feedblock	Group		Intake g/head/day DM	Salt	Urea	Total urea
1	CSE	C	SBPU+	384 ± 54	56	10	28
		D	SBP	684 ± 85*	99	18	18
2	W290(76)	C	SBPU	656 ± 68	38	34	54
		D	SBP	1382 ± 58***	80	71	71
3	RHE	C	SBPU	269 ± 39	33	8	28
		D	SBP	263 ± 37NS	32	8	88
4	W291(76)	C	SBPU	347 ± 45	11	18	38
		D	SBP	395 ± 70NS	12	20	20
5	CSE	C	BV	828 ± 73	120	22	22
		D	B	883 ± 75NS	128	23	23
6	W290(76)	C	BV	830 ± 52	48	42	42
		D	B	838 ± 57NS	49	43	43
7	W290(76)	C	SBPU	554 ± 33	32	28	48
		D	SBP	1048 ± 63***	60	54	54

+ supplies approximately 20 g urea.

The intake of urea from the feedblock and also total urea intake, was greatest (71 g/head) for group D ewes given the W290(76) block (period 2). Group C ewes given SBPU had higher total urea intakes than group D ewes in periods (1), (3) and (4), when receiving CSE, RHE and W291(76) feedblocks, respectively. The lowest total intakes of 8 and 20 g/head respectively occurred during periods (3) and (4) when group D ewes received SBP.

Discussion

The response of the sheep to the provision of additional nitrogen varied depending on whether NPN (urea) or preformed protein (vegetable protein) was given. When urea in the SBPU nut was made available to sheep also receiving high-intake (substitute-type) feedblocks (CSE and W290(76)), the feedblock intake was considerably reduced. When preformed protein in the barley-vegetable pellet was given to the same sheep and supplying approximately similar quantities of crude protein, the feedblock intake was no different from ewes receiving barley alone. This tends to suggest that no nitrogen regulatory mechanism was operating and the decrease in substitute-type feedblock intake when extra nitrogen was made available was peculiar to urea.

The most likely explanation for this decreased intake is that the ewes receiving SBPU, in addition to a large input of urea from the feedblock, suffered what can best be called a subclinical urea toxicity which discouraged further feedblock consumption.

The ewes in this experiment weighed about 70 to 90 kg, which gave a total urea intake of 0.3 to 0.4 and 0.6 to 0.8 g urea/kg live weight, for group C sheep (SBPU) on CSE and W290(76) feedblock, respectively. However group D ewes given only SBP had higher urea intakes, 0.8 to 1.0 g/kg live weight on the W290(76) block.

Urea toxicity is more likely to result when urea is given suddenly as by drench (e.g. Dinning, Briggs, Gallup, Orr and Butler 1948; Clark, Oyaert and Quinn 1951) or if the diet is deficient in digestible carbohydrate or if animals have been starved or fasted. Toxic quantities of urea given as a drench to sheep have been between 0.28 and 0.44 g/kg live weight. (Oltjen, Waller, Nelson and Williams, 1968). The sheep in the present experiment were receiving far more urea during periods 1, 2 and 7, than has been shown to be toxic when given in drench form, but over a 24-hr time interval.

Therefore it appears not to be the quantitative intake of urea per se but how the urea is consumed and over what time interval, which affects the extent of appetite depression (subclinical toxicity), when large amounts of urea are given. When sheep are given feedblocks under housed conditions the frequency of individual visits to the block was shown to be considerable (Expt 2.1). Therefore the pattern of urea intake was likely to be 'little and often' for the sheep given feedblock in this experiment. However group C ewes received an allocation of urea (20 g/head) in one daily feed, in addition to the urea from feedblocks. It was noticed that after receiving the SBPU, group C ewes ceased to show interest in the feedblocks and spent several hours lying down. This is consistent with the hypothesis that the relatively large amount of urea (mean = 20 g/head) consumed in a short time period, depressed appetite (metabolic depression) of group C sheep and lowered feedblock intake. Whilst consuming more urea in period (2), group D sheep were protected from subclinical toxicity by the frequent pattern of urea intake.

Although group D ewes consumed significantly more W290(76) feedblock when given SBP (period 1) than barley (period 2), this probably reflects the daily introduction of a new feedblock during period (1) and only every second day during period (2), rather than a difference in the nature of the foods. The intakes of CSE when either SBP or barley were given to the sheep (group D) were not significantly different.

The total urea intake (28 g/head) by group C sheep (period 1) receiving CSE feedblock at which feedblock intake was reduced (384 g/head), was only half the urea intake (54 g/head) during period 2, when the same sheep consumed 656 g/head of W290(76) feedblock. Therefore absolute intake of urea was not the only criterion of appetite regulation, nor probably a very significant one in this particular case. Salt also appeared to be importantly involved in the mechanism. The respective salt intakes when 1 g of urea was consumed from the CSE (feedblock) and W290(76) feedblocks were 5.6 and 1.1 g. It would be reasonable to expect salt to be more important in restricting CSE intake at any intake of urea than for the W290(76) feedblock. Alternatively, the W290(76) has a greater intake potential.

The consumption of the lower intake (supplement-type) feedblocks (RHE and W291(76)) was not affected by the provision of additional nitrogen as urea. This suggests that maximum feedblock intake had already been reached and constraints other than salt and/or urea intake had limited intake. The salt intakes for these supplement feedblocks were only about 11 to 33 g/head compared with 30 to 130 g head for the substitute feedblocks. The most probable first limiting constraint on the intake of the supplement feedblocks used here (discounting factors inherent in the animal or external influences) was block hardness.

The hardness of W291(76) is determined by pressure imparted during extrusion and the use of a binding reaction (molasses and calcium hydroxide) to form calcium surcosate. The hardness of RHE is imparted by moderate compression, allied to the use of EC feed (a distillery by-product possessing excellent binding properties). Both calcium sucrosate and EC feed may also influence feedblock intake indirectly as both can be shown to be unpalatable to ruminants.

The results of Expt 8.1 failed to show how any consistent nitrogen regulatory mechanism for feedblock intakes. However, assuming that the sheep and environmental factors were relatively constant between experimental periods some of the factors inherent in the block per se which regulate intake were identified. For example physical hardness appeared to be the first limiting intake factor, total salt intake the second and then perhaps unplalatability of other feedblock nutrients such as urea and EC feed.

Expt 8.2 The effect on feedblock (RS) intake of varying the qualitative and quantitative intake of other dietary constituents

Introduction

In Expt 8.1 it was shown that the intakes of both the substitute-type W290(76) and CSE feedblocks were not affected when extra nitrogen was given as preformed vegetable protein but were significantly lowered when a single feed of urea in molassed sugar beet pulp was introduced. The intake of the supplement-type RHE and W291(76) feedblocks was slightly but not significantly lowered when additional urea was given in a single meal. The mean daily intake of about 20 g additional urea, appeared sufficient to 'metabolically' depress feedblock intake. The sheep in that experiment received the urea-containing food in a competitive group situation and it is possible that the distribution of the total amount given was very unequal between individuals. Therefore the decrease in feedblock intake may have been due to a proportion of individuals completely ceasing to consume feedblocks, rather than a uniform decrease intake by all the sheep in the group.

To overcome this possible complication (unequal nutrient distribution), additional nutrients were given to individual sheep in Expt 8.2 by drenching for several of the treatments. The main objective of the experiment remained unchanged in that the effect of up-grading the nitrogen and/or energy status on feedblcok intake was examined. Only one type of feedblock was used in Expt 8.2 (RS), which aims principally to improve the utilisation of roughages. The intake of this block is claimed to be regulated in a manner reflecting roughage quality (high quality roughage, low feedblock intake and vice versa).

Materials and Methods

Thirty mature Scottish Half bred (Border Leicester ♂ x Cheviot ♀) or Greyface (Border Leicester ♂ x Scottish Blackface ♀) wethers, initially weighing between 41 to 87 kg were divided into 2 groups (C and D) on the basis of breed and live weight. The wethers were housed and bedded on poor quality barley straw.

Each group received a single RS feedblock (Proximate analysis given in Table 1) with no container. The blocks were weighed daily at 09.00 hr and a new block introduced when less than the previous days consumption remained, and the residue was removed. The sheep were additionally given the treatments outlined in Table 24 for periods each of 17 days duration (136 days in total), when appropriate an approximate estimate of roughage intake was made by recording the total group consumption over days 11 to 17. Long roughages were given in Norwegian box feeders to minimise wastage. The intakes of RS feedblock over days 8 to 17 of the various treatment periods were compared for each group of sheep.

The sheep were weighed on the last day of each treatment period.

The fish meal, urea and sucrose doses were prepared and administered by mixing or dissolving in about 0.5 to 1.0 l of warm water. Bottles of appropriate size were used for drenching.

Results

Most sheep progressively lost live weight (Fig 14) during periods 1 to 5 when the only roughage available was barley straw. The magnitude

Fig.14 Expt 8.2 Live-weight changes during the various treatment periods.

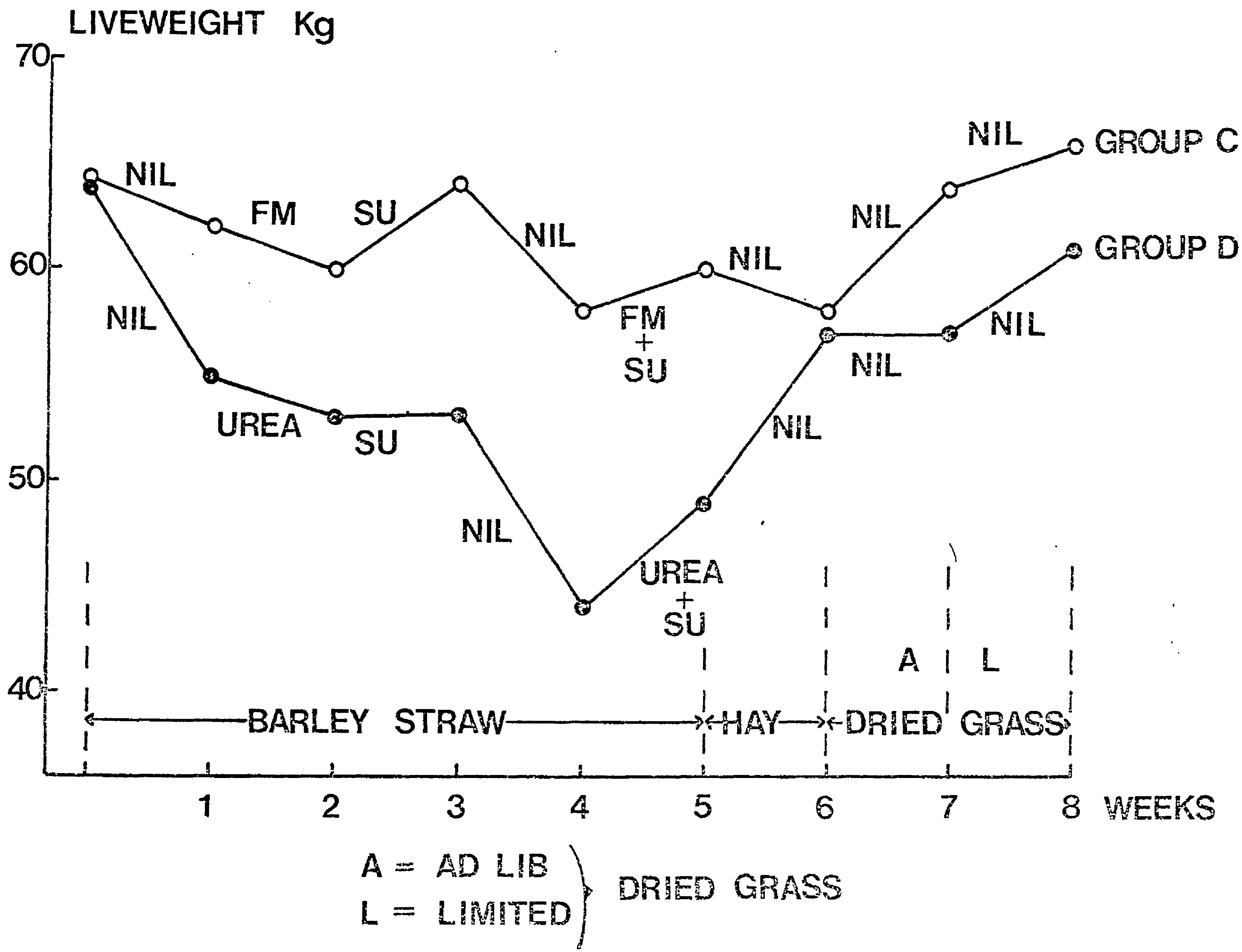

LIVEWEIGHT Kg
70
60
50
40
NIL
FM
SU
NIL
FM + SU
NIL
NIL
NIL
GROUP C
NIL
UREA
SU
NIL
UREA + SU
NIL
NIL
NIL
GROUP D
A
L
BARLEY STRAW
HAY
DRIED GRASS
1
2
3
4
5
6
7
8
WEEKS
A = AD LIB
L = LIMITED
DRIED GRASS

Table 24 Expt 8.2 Description of treatments used and their sequence

Period	Group C	Group D
(1)	Ad libitum barley straw +	Ad libitum barley straw
(2)	Ad libitum barley straw plus 94 g DM fish meal (700 g CP/kg DM) equivalent to mean CP intake (66 g) from RS during Period (1). Given in 2 doses (08.00 and 16.00 hrs) of 47 g.	Ad libitum barley straw, plus 22 g urea, equivalent to mean CP intake (62 g) from RS during Period (1). Given in 2 doses (08.00 and 16.00 hr) of 11 g.
(3)	Ad libitum barley straw plus 148 g (1.88 MJ ME) sucrose (ME = 12.7 MJ/kg) equivalent to mean ME intake from barley ** in RS during period (1).	Ad libitum barley straw plus 133 g (1.69 MJ ME) sucrose, equivalent to mean ME intake from barley in RS during period (1)
(4)	Period (1) repeated	Period (1) repeated.
(5)	Periods (2) and (3) combined	Periods (2) and (3) combined
(6)	Ad libitum hay ++	Ad libitum hay
(7)	Ad libitum dried grass cubes *	Ad libitum dried grass cubes
(8)	1.14 kg DM/head/day of dried grass cubes. (50% of ad libitum level in Period 7)	1.05 kg DM/head/day of dried grass cubes. (50% of ad libitum level in Period 7)

+ 30 g CP, 381 g CF/kg DM

++ 87 g CP, 366 g CF, 12 g EE, 63 g Ash, 472 g NFE/kg DM. * 142 g CP, 221 g CF, 25 g EE, 76 g Ash and 536 g NFE/kg DM.

** The RS feedblock was assumed to contain 500 g barley/kg (Sarif-Sarban and Menke 1970).

of this loss was greatest for group D, when the live-weight loss (23%) over periods 1 to 5 was significant ($P < 0.01$). The respective change in live weight (7%) for group C was not significantly different from the initial live weight. There was a significant ($P < 0.05$) reduction in live weight for group D sheep during period 4, when block plus straw only was given. The live weight of group D sheep increased when hay replaced the barley straw.

The mean daily intakes of feedblock and roughage DM, CP and ME for the various treatment periods are given in Table 25.

The mean daily intakes of RS during periods 1 and 4, when barley straw alone was given, were not significantly different for both groups C and D. The estimated intakes of barley straw were however 12 and 35% greater in period 1 than period 4 for group C and D, respectively.

The mean daily intake of RS by group C was significantly ($P < 0.05$) increased (26 and 20% greater than periods 1 and 4, respectively) when fish meal was given (period 2). The RS intake by group D was significantly ($P < 0.01$ and $P < 0.05$) reduced (31 and 26% less than periods 1 and 4, respectively) when urea alone was given (period 2). When both urea and sucrose were given (period 5) the mean feedblock intake (163 g/head) was also significantly ($P < 0.01$) below the intakes when block and straw only was given (periods 1 and 4).

The feedblock intakes (274 and 191 g for groups C and D, respectively) when sucrose alone was given to the sheep (period 3) were not significantly different from the intakes in periods 1, 4, 5 and period 2 (group D only). In period 3 the RS intake by group C was reduced significantly ($P < 0.05$) from 344 g/head in period 2 to (274 g/head) a level equivalent with period 1 (273 g/head).

The mean daily intakes of barley straw over periods 1 to 5 did not appear to vary consistently with the treatments imposed.

When hay was given (period 6) the RS intakes (120 and 120 g) were 57 and 49% less for groups C and D, respectively, than the mean of periods

Table 25 Expt 8.2 Mean daily DM, CP(g) and ME(MJ) intakes for sheep given roughage, feedblock and additional supplements

	GROUP C								GROUP D							
Period	Additional Supplement/ Roughage	Roughage			Feedblock			Total +	Additional Supplement/ Roughage	Roughage			Feedblock			Total +
		DM	CP	ME	DM	CP	ME	ME		DM	CP	ME	DM	CP	ME	(ME)
1	Ad libitum barley straw	935	28	6.8	273±23	66	2.4	9.2	Ad libitum barley straw	1000	30	7.3	245±15	60	2.2	9.5
2	Ad libitum barley straw + Fish meal	860	26	6.3	344±16	84	3.1	10.4	Ad libitum barley straw + urea	850	26	6.2	169±10	41	1.5	7.7
3	Ad libitum barley straw + sucrose	910	27	6.6	274±17	67	2.4	10.9	Ad libitum barley straw + sucrose	825	25	6.0	191±9	46	1.7	9.4
4	Ad libitum barley straw	835	25	6.1	286±17	70	2.5	8.6	Ad libitum barley straw	725	22	5.3	227±17	55	2.0	7.3
5	Ad libitum barley straw + Fish meal + sucrose	1020	31	7.5	250±9	61	2.2	12.6	Ad libitum barley straw + urea + sucrose	780	23	5.7	163±9	40	1.5	9.9
6	Ad libitum hay	1020	89	8.4	120±11	21	1.1	9.5	Ad libitum hay	1055	92	8.7	120±23	29	1.1	9.8
7	Ad libitum dried grass cubes	2270	322	24.3	81±27	20	0.7	25.0	Ad libitum dried grass cubes	2100	298	22.5	61±38	15	0.5	23.0
8	Dried grass cubes (50% Ad libitum)	1140	162	12.2	215±24	52	1.9	14.1	Dried grass cubes (50% Ad libitum)	1050	149	11.2	253±24	62	2.3	13.5

+ including ME from sucrose and/or Fish meal.

1 and 4 (280 and 236 g) when straw alone was given. The mean daily DM intakes of hay (1020 and 1055 g for groups C and D, respectively) were only slightly greater than the mean intakes of barley straw DM for periods 1 and 4 combined (980 and 890 g).

When dried grass cubes were given ad libitum (period 7) the mean daily intakes of RS feedblock (81 and 61 g/head) were 71 and 74% less than when straw was given (periods 1 and 4) and also 33 and 49% less than when hay alone was given (period 6), for groups C and D, respectively. The difference was significant ($P < 0.001$) between straw and dried grass cubes but not significant for hay or dried grass cubes. When dried grass cubes were given at 50% the ad libitum level (1.1 kg DM/head), the mean daily intakes of RS were increased (215 and 253 g/head) (165 and 315% for groups C and D, respectively) above the intakes (81 and 61 g/head) when dried grass cubes were provided ad libitum. These increases were significant ($P < 0.01$ and $P < 0.001$). The consumption of RS feedblock was now no different from when straw plus block alone was given.

Discussion

The data quoted for straw intakes in particular were only approximate values due to the difficulty of minimising wastage. When hay was given the wastage was less but still considerable, but little wastage occurred with the dried grass cubes. Nevertheless, roughage intake tended to increase with roughage quality (digestibility) as expected. For group C sheep the highest barley straw intake coincided with the giving of fish meal plus sucrose. The CP content of the diet for both groups of sheep from a combination of feedblock and barley straw was never less than about 80 g CP/kg DM and it was therefore unlikely that the additional nitrogen from the drenches of urea or fish meal would increase straw intake further. In the periods when either hay or dried grass cubes were given the CP in the total diet was always more than adequate i.e. about 80 g CP/kg DM.

The calculated intakes of ME varied between 7.2 MJ ME (period 4, group D) to 25.0 MJ ME (period 7, group C). The ME content of the RS feedblock was assumed to be 8.9 MJ/kg DM (MEF = 0.012 CP + 0.031 EE + 0.0005 CF + 0.014 NFE), the ME contents of the barley straw, hay and dried grass cubes were assumed to be 7.3, 8.2 and 10.7 MJ/kg DM, respectively. The ME of the latter was calculated from the results of an in vivo digestibility trial (MEF = 0.15 DOMD%). The ME maintenance requirement (MAFF et al., 1975) for housed sheep of 64 kg live weight is 7.2 MJ. Therefore the mean ME intake was always at least equivalent to the mean requirement. However, particularly when barley straw plus feedblock only was given a considerable live-weight loss was recorded. This may be due to several reasons such as an overestimation of straw intake because of wastage or an unequal distribution of the total straw or feedblock consumed between sheep (although virtually all sheep lost weight when straw plus block alone was given). Also because of the very soft faeces produced by the sheep indicative of a digestive upset, a depressing effect of salt and/or other feedblock ingredients on roughage utilisation (as was recorded with RHE in digestibility trials, Page 75) cannot be disregarded. Even when the sheep were consuming a mean ME intake from dried grass cubes of above 12 MJ/head (period 8), plus a considerable amount of feedblock, the live-weight gains were considerably less than anticipated.

Whenever the daily intake of RS exceeded about 150 to 200 g DM/head, the bedding became very wet and it was almost impossible to keep the sheep clean without using a ridiculously large amount of straw. This is almost certainly due to the increased water consumption required to excrete the considerable salt intakes (up to 55 g/head/day or nearly 43 g salt/kg diet DM) from feedblock alone. Clearly this situation would be very undesirable and costly in practice.

The effect of giving additional urea (22 g) in this experiment, in two equal daily drenches was consistent with the results of Expt 8.1, with the substitute-type W290(76) and CSE feedblocks (20 g urea given in sugar beet pulp). In both experiments feedblock intake was probably reduced due to a subclinical urea toxicity (metabolic depression). In Expt 8.2 the urea given in a single drench (11 g) was between 0.15 to 0.33 g urea/kg live weight, whilst the total urea intake from both the feedblocks (60 g urea/kg) and 2 daily drenches (22 g) varied between 0.43 to 0.97 g urea/kg live weight. Toxic quantities of urea given as a drench to sheep have been between 0.28 and 0.44 g/kg live weight (Oltjen, Walker, Nelson and Tillman, 1963 and Russel, Hale and Hubert, 1962).

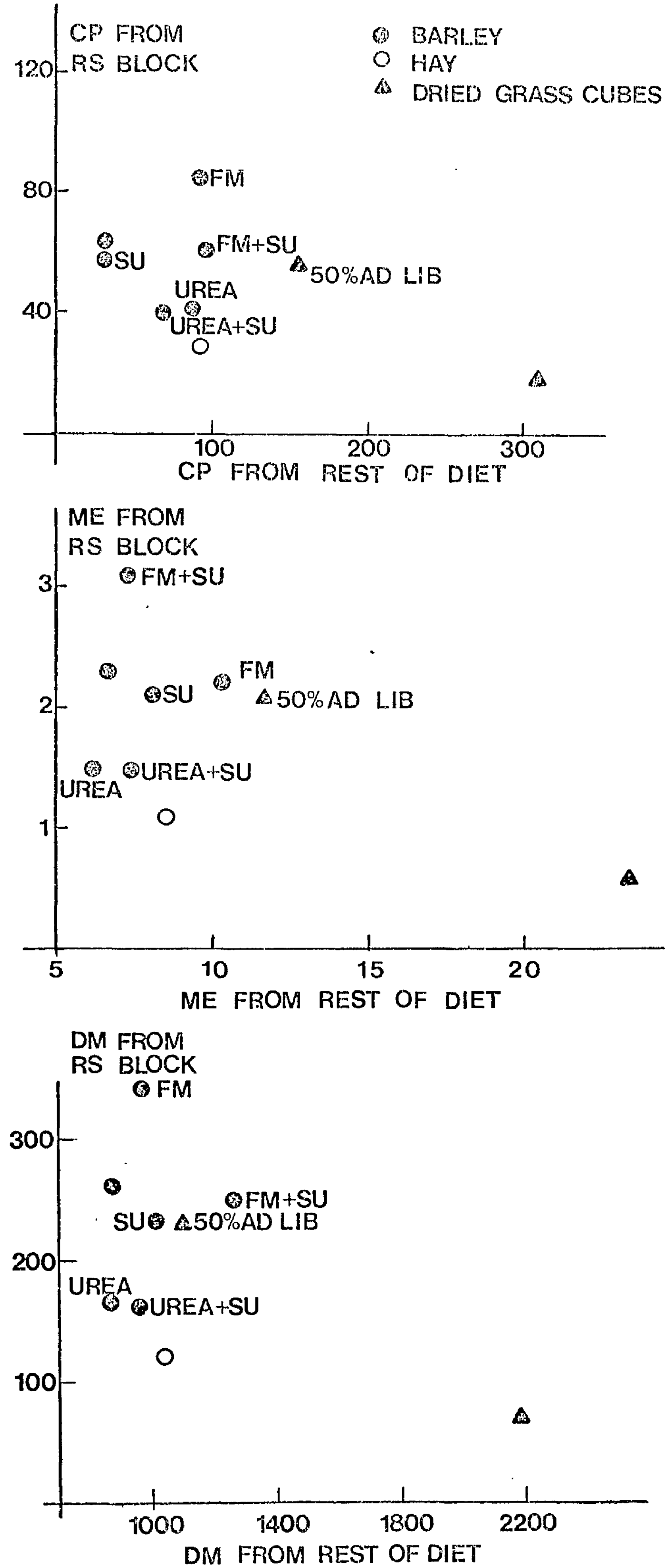
When the nitrogen (protein) status of group C sheep was upgraded using fish meal, the effect on feedblock consumption varied depending on whether sucrose was given. Fish meal alone significantly increased feedblock intake but fish meal and sucrose together had no effect compared when neither were given. No satisfactory explanation can be offered for this response to fish meal alone (sucrose alone had no significant effect on feedblock intake for both groups of sheep) from the limited data available. As in Expt 8.1, the provision of additional nitrogen as preformed protein (fish meal) did not result in any reduction of feedblock intake, indicative that no protein regulatory mechanism appeared to exist.

The introduction of small amounts of ME as sucrose (1.7 to 1.9 MJ) and fish meal (about 1.0 MJ ME), to increase total ME intake by about 32 and 18% for groups C and D, respectively did not significantly alter feedblock intake. However, when a more fundamental upgrading of energy status was made by changing the quality of the roughage given, feedblock intake decreased with increasing roughage quality (Fig 15). The sheep in both groups consumed most block when a poor quality roughage (barley

Fig.15a Expt 8.2 The relationship between CP consumed (g/head/day) from RS feedblocks and CP consumed from rest of the diet, comprising various roughages given alone or with drenches of either fish meal (FM) or urea with and without sucrose (SU).

Fig.15b The relationship between ME consumed (MJ/head/day) from RS feedblocks with ME consumed from rest of the diet.

Fig.15c The relationship between consumed (g/head/day) from RS feedblocks with DM consumed from rest of the diet.


CP FROM
RS BLOCK
BARLEY
HAY
DRIED GRASS CUBES
120
80
40
FM
SU
FM+SU
50%AD LIB
UREA
UREA+SU
100
200
300
CP FROM REST OF DIET
ME FROM
RS BLOCK
3
2
1
FM+SU
FM
SU
50%AD LIB
UREA+SU
UREA
5
10
15
20
ME FROM REST OF DIET
DM FROM
RS BLOCK
300
200
100
FM
FM+SU
SU
50%AD LIB
UREA
UREA+SU
1000
1400
1800
2200
DM FROM REST OF DIET

straw) was given, an intermediate quantity when medium quality roughage (hay) was given and only a small quantity of block with high quality roughage (dried grass cubes). An approximate regulation of feedblock intake according to the gross qualitative nature of the diet did appear to operate. This is consistent with the observations made in Section 2 that ruminants at 'lush' spring grass (very high quality roughage) refuse to eat feedblocks. When the quantity of dried grass cubes allocated was halved feedblock intake increased appreciably until the sheep had probably reached the upper intake limit, imposed by constraints within the block.

These fluctuations in feedblock intake, reflecting either roughage quality or quantity (perhaps the same thing, because a limited amount of high quality roughage is approximately similar to providing ad libitum poor quality roughage, in that total nutrient intake is reduced) are in most cases not likely to prejudice the health or productivity of the animal. The exception is that when feedblocks are used as carriers of magnesium to combat hypomagnesaemic tetany in the spring (Part C of this section).

The critical question to be answered and also the major objective of this section is are these changes in feedblock intake motivated by nutritional need or do they reflect differences in palatability (taste) and the ability of animals to reach a satiated state, with a consequent feeling of 'well-being.'

In the case of the barley straw and hay, the appetite limit is almost certainly governed by the physical constraints of the roughage bulk. It would also be reasonable to assume that the hay would be more palatable than the barley straw and allow a greater nutrient (ME) intake. The animals would then have less desire to consume relatively unpalatable feedblock material. The intake of the dried grass cubes when offered ad libitum would be limited by metabolic constraints on voluntary food intake, and the sheep would become satiated on palatable material without recourse to the less palatable feedblock. The low level of consumption with ad libitum dried grass cubes probably reflects a novelty interest only, or desire for salt, which is one nutrient clearly shown to be consumed according to need, Denton (1967, 1969).

In some respects the intake of feedblocks does appear to be regulated in gross terms according to the quantity and palatability of the other consumable DM available to animals. Alternatively, ruminants consume feedblocks in greater amounts when they are hungry. There does not however appear to exist any more subtle physiological mechanism whereby feedblock intake is regulated to equate nitrogen or ME intakes with needs.

B An investigation into the ability of ewes to consume feedblock material according to their energy requirements, over the final 6 weeks of pregnancy

Introduction

Two experiments were conducted to examine whether a quantitative regulation of feedblock intake for energy was possible amongst groups of ewes containing non pregnant, single and multi-gravid animals, during the final 6 weeks of pregnancy. In both experiments feedblocks of the substitute-type were used, to allow the widest possible range of intakes before constraints inherent in the feedblock and external factors strongly inhibited feedblock consumption. The feedblocks used were also relatively high in ME, affording in theory the opportunity for multi-gravid ewes to consume a large proportion of their total ME requirements from feedblock.

The first experiment was carried out indoors to obtain maximum control over the experimental conditions. Only two dietary components were made available, dried grass cubes and feedblock. In the second experiment the sheep were allowed access to a 4 ha paddock which initially offered a small amount of grazing. Subsequently the only major dietary components were hay and feedblocks.

Expt 9.1. Energy regulation aspects of feedblocks using pregnant housed sheep

Materials and Methods

The experiment was carried out during February and March 1975, over the last 30 days prior to the expected date of parturition. Thirty six mature Greyface (Border Leicester ♂ x Scottish Blackface ♀) ewes, weighing 56 to 90 kg live weight were assumed to be pregnant following mating, subsequent to oestrus synchronisation using intra-vaginal pessaries.

The ewes were divided into two groups (E and F) of 18 animals, on the basis of live weight and body condition score. Group E contained ewes in heavier (Mean live weight = 81 kg) and better condition than ewes in group F (Mean live weight = 65 kg). The dental status of the ewes was variable and some individuals had their central incisor teeth absent. The ewes were bedded on sawdust.

Both groups of ewes were given individually (by penning for 15 minutes daily at 09.00 hr) an allocation of dried grass cubes (930 and 760 g DM for groups E and F, respectively) of composition 137 g CP, 207 g CF, 21 g EE, 76 g Ash and 559 g NFE/kg DM. The DE and DCP (13.0 MJ and 92 g, respectively) contents of the dried grass cubes were determined using 8 mature Greyface wethers in metabolism cages. The ME value of the grass cubes (10.5 MJ/kg) was calculated using the equation MEF = DOMD% x 0.15. The ME intakes from the dried grass cubes were 9.8 and 8.1 MJ/head for groups E and F, respectively, or 13 and 11% in excess of the MAFF et al. (1975) requirements for maintenance (8.7 and 7.2 MJ), for ewes of these live weights.

Each group of ewes was also given a single W290(74) feedblock of similar mean composition to that shown in Table 1. The ME and DCP contents of the feedblock (8.0 MJ and 168 g/kg DM, respectively) were determined in vivo using mature Greyface wethers, using the technique described on page 74. The total group intake of feedblock material was measured by daily weighing and the level of intake attained by both groups of ewes necessitated the introduction of a new block each day. The feedblocks containing chromic oxide (2.42 g/kg DM).

The ewes were equipped for total quantitative faecal collections using harnesses and nylon mesh bags. Four collections each of 4-days were made during each of the final 4 weeks of pregnancy. The daily faecal outputs from individual ewes were sampled according to Method 1 (Page 71). The individual feedblock intakes for the respective collection periods were calculated from the total chromic oxide recovered in the faeces and the concentration of chromic oxide in the feedblocks.

Blood samples were obtained from each ewe at 10.00 hr on day 3 of the collection periods for the determination of total ketones, plasma FFA and urea.

Upon completion of the 4th collection period, subjective reassessment of dental status was made, with individual ewes being allocated to one of 5 categories (A to E), using the criteria outlined in Expt 2.1.

After lambing the ewes and their lambs were weighed. In the computation of the results the data from both groups (E and F) have been combined. The total ME intakes from dried grass cubes and feedblock were calculated for individual ewes and compared with the theoretical requirements (MAFF et al. 1975).

Results

On several days the feedblocks given were totally consumed after about 20 hours, particularly for the heavier (group E) ewes and a new feedblock was not introduced until 24 hours elapsed, because the faeces from the ewes were already very soft and a higher feedblock intake might have made quantitative collection of faeces impossible. The allocations of grass cubes given were readily consumed within 10 to 15 minutes, with the exception of one ewe in group E, which refused to consume the grass cubes rapidly.

The mean feedblock intakes, litter weights and percentage change in live weight for the various collection periods are given in Table 26, for groups E and F separately and when combined on the basis of number of lambs born. The number of ewes in both groups non-pregnant or producing 1, 2 or 3 lambs was 3, 12, 17 and 4, respectively. One ewe carrying triplets (group E) died lambing and the data for this ewe is not included in the litter weight or percentage change in ewe live weight.

Table 26. Expt 9.1. Mean feedblock intake (g), litter weight (kg) and percentage change in ewe live weight (± SE)

Collection Period (days of pregnancy)	120-124	128-131	135-138	141-145	Mean over 4 collections	Litter weight kg	% change in ewe live weight
Group E [+] 18 ewes	753(27.2)[δ]	896(27.7)	1007(38.5)	897(33.2)	888(25.5)	9.0±0.4	-7.7±1.2
Group F [++] 18 ewes	648(39.4)	791(36.6)	842(39.1)	750(29.7)	757(34.4)	6.1±0.4	-2.1±0.8
Mean of all 36 ewes	701	844	924	824	823	7.6±0.4	-4.1±0.7
Groups E and F combined							
Barren 3 ewes	633(19.0)	629(46.6)	655(34.7)	532(50.4)	612(36.5)	—	-3.1±0.4
Single 12 ewes	701(37.1)	892(28.8)	930(36.0)	878(27.3)	850(28.4)	5.3±0.4	-3.0±0.9
Twins 17 ewes	669(38.6)	850(33.5)	874(46.7)	772(31.2)	796(34.4)	8.5±0.4	-5.0±1.1
Triplets 4 ewes	837(11.6)	951(24.7)	1182(20.9)	1172(4.9)	1035(10.2)	10.5±0.1	-6.8±2.3

[+] Includes 1 ewe which died during lambing which is not included in litter weight and % change in ewe live weight data.

[++] Includes 3 barren sheep which are discounted in the litter weight comparisons. [δ] CV%

During each collection period the heavier ewes in group E consumed more feedblock per head (17% over all 4 collections) than group F ewes, the difference however was not significant. The CV for feedblock intake (27 to 39%) with 18 ewes per group were of the same order for groups of 16 ewes on W290(74) in Expt 2.1. All ewes consumed feedblock. The minimum daily feedblock consumption by any ewe was 227 g DM/head. There was a progressive increase in feedblock consumption (34 and 30% for groups E and F respectively) from collection 1 (121 to 124 days of pregnancy) to collection 3 (135 to 138 days of pregnancy). This increase was significant ($P < 0.05$) for group E ewes. In the final collection before parturition (days 141 to 142) the mean intakes for both groups of ewes decreased.

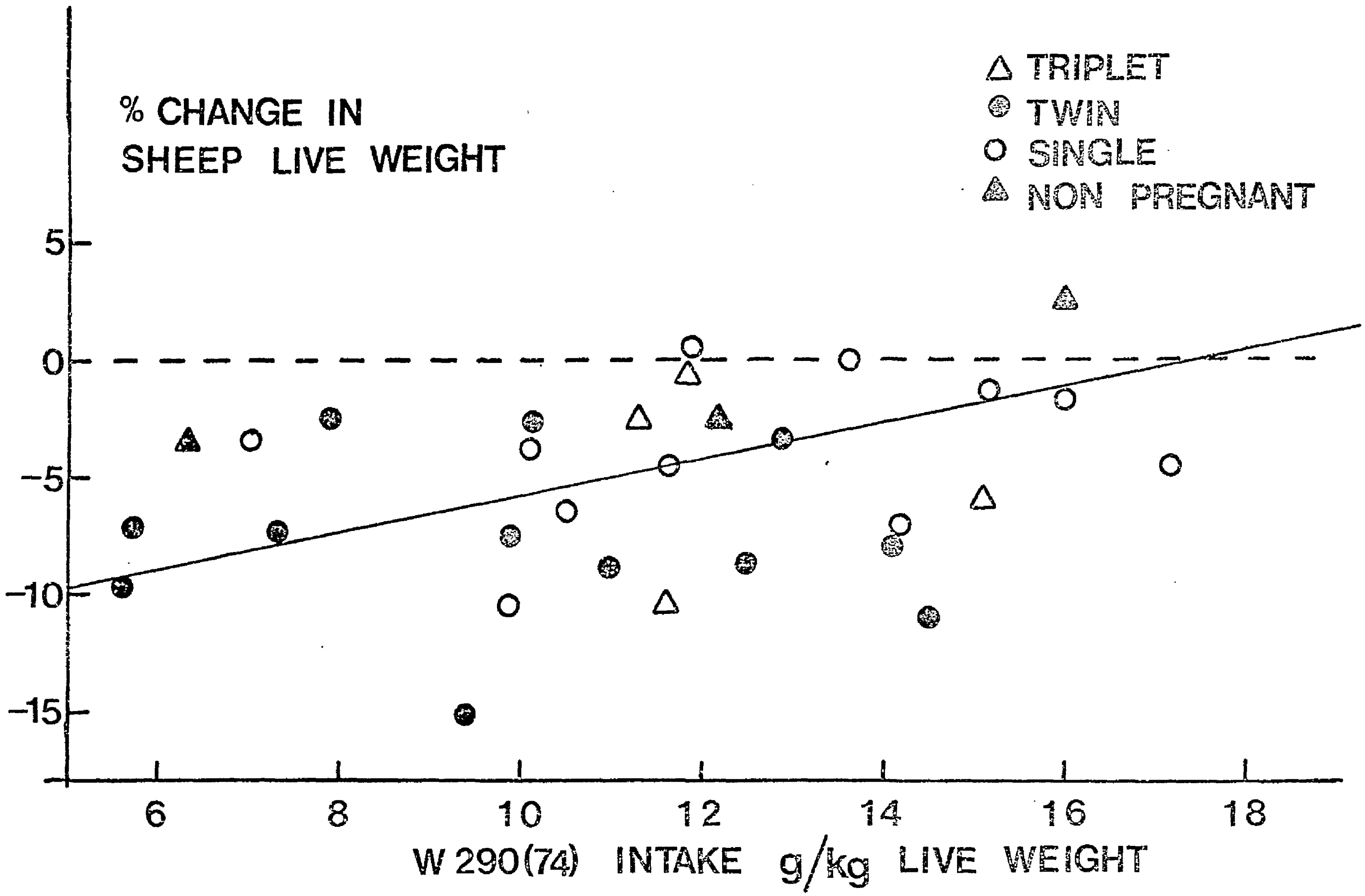
The mean feedblock intake (1035 g DM/head over 4 collections) for ewes carrying triplets was 69% greater than that for barren ewes (612 g DM head), but the difference was not significant because of the small numbers of sheep in each category. There were no significant differences in feedblock intake, between ewes carrying twins (mean over 4 collections = 796 g DM/head) and ewes carrying a single foetus (850 g DM/head) in any of the collection periods, the ewes with single foetus in fact consumed slightly more feedblock. The four ewes carrying 3 foetuses, consumed a mean 22 and 30% more feedblock over all collections than the ewes carrying single or twin foetuses, respectively. The differences were not significant due to the small number of animals with triplets.

The heavier group E had a significantly ($P < 0.001$) higher mean litter weight (9.0 kg) than the lighter group F ewes (6.1 kg). This largely reflected the greater number of twins and triplets in group E. However the ewes in group E lost significantly ($P < 0.01$) more live weight over the experimental period. There were no significant differences in live weight change, irrespective of the number of foetuses present over the experimental period, although those ewes with 2 or more foetuses lost more weight than single or barren ewes (Table 26). The percentage change in live weight for all ewes from day 117 of pregnancy to after parturition was significantly ($P < 0.01$) correlated ($r = 0.449$) with the mean overall feedblock intake/kg live weight (on day 117 of pregnancy). The data are presented graphically in Fig 16. There was no significant correlation between the litter weight of ewes with a single foetus and feedblock intake. The block intake of ewes carrying 2 or more foetuses was significantly correlated ($P < 0.01$) with litter weight ($r = 0.595$). The relationship between feedblock intake and litter weight for individual ewes is presented in Fig 17.

Upon completion of collection 4 (days 141 to 144) the dental status of the ewes was reassessed and individuals allocated subjectively to one of 5 dental categories (A, B, C, D and E). The number of ewes in each category was 6, 3, 3, 1, 5 and 9, 1, 3, 2, 3 for groups E and F, respectively. There appeared to be no relationship between dental status and number of foetuses carried, but when the mean feedblock intakes of categories A + B ewes were compared with categories D + E ewes (917 ± 53 v. 679 ± 78 g DM/head), the 35% difference in intake of A + B ewes was significantly ($P < 0.05$) higher.

The determined ME intakes (grass cubes + feedblock) and MAFF et al. (1975) ME requirements for the ewes are presented in Table 27. There was a tendency for ME intake to increase over collections 1 to 3 (days 121 to 138 of pregnancy) for pregnant ewes (the ME intake of non-pregnant ewes was constant over the same period), which reflected the changes in feedblock consumption (Table 26). In the final faecal collection of pregnancy (days 141 to 144) the mean ME intakes decreased, irrespective of uterine burden. In general all ewes consumed feedblock well in excess of MAFF et al. (1975) ME requirements. The only instance where mean ME requirement exceeded total ME intake was for ewes with twin foetuses during the final collection (days 141 to 144)

Fig.16 Expt 9.1 The relationship between W290(74) intake (g DM/kg/ live weight) measured over 4 special collections during late pregnancy and % change in ewe live weight.


% CHANGE IN
SHEEP LIVE WEIGHT
TRIPLET
TWIN
SINGLE
NON PREGNANT
5
0
-5
-10
-15
6
8
10
12
14
16
18
W 290(74) INTAKE g/kg LIVE WEIGHT

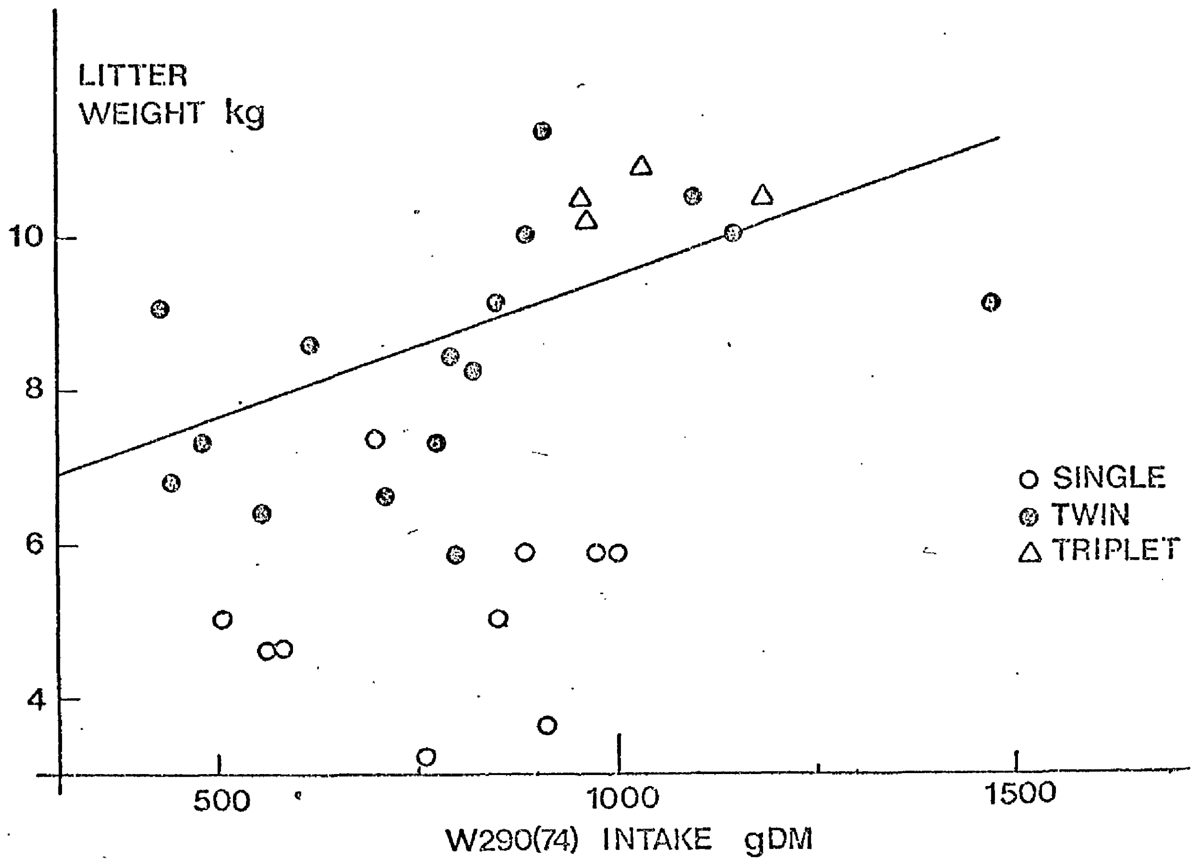


Fig.17 Expt 9.1 The relationship between total litter weight (kg) and mean W290(74) feedblock intake (g DM/head/day) employing 4 faecal collections during late pregnancy for ewes carrying single, twin and triplet foetuses.

of pregnancy. The mean ME requirement of the ewes (16.3 MJ) was 9% in excess of the ME intake (15.0 MJ). Eleven of the individual ewes with twin foetuses failed to meet their ME requirements from days 141 to 144. During the 3rd collection (days 135 to 138) of pregnancy, 5 ewes with twin foetuses consumed below their ME requirements. In collections 1 (days 121 to 124) and 2 (days 131 to 134) the number of ewes with twin foetuses consuming below their maintenance requirements were 3 and 4, respectively. Ewes failing to consume their ME requirement over more than 1 collection period (4) were all assigned to dental category E.

Table 27. Expt 9.1. Calculated total ME intakes (MJ) and ME requirements (MAFF et al. 1975) for ewes housed in late pregnancy

	ME (MJ)			
Collection Period days of pregnancy	121-124	128-131	135-138	141-144
Barren ewes (3)+				
ME intake	12.3±0.6	12.2±1.4	12.4±1.1	11.5±1.3
ME required	6.3±0.2	6.3±0.2	6.3±0.2	6.3±0.2
Single foetus (12)				
ME intake	13.3±1.3	14.8±0.8	15.1±0.9	14.7±0.7
ME required	10.3±0.3	10.9±0.2	11.5±0.3	12.1±0.3
Twin foetuses (17)				
ME intake	14.2±0.6	15.4±0.7	16.2±0.9	15.0±0.7
ME required	12.9±0.3	13.9±0.3	15.1±0.4	16.3±0.4
Three foetuses (4)				
ME intake	16.5±0.4	17.4±1.0	19.1±1.1	19.2±0.3
ME required	13.9±0.5	15.1±0.5	16.3±0.5	17.6±0.6

+No. of ewes.

The non-pregnant ewes (3) consumed almost twice their MAFF et al. (1975), mean maintenance requirement in all collections. The ewes carrying a single foetus significantly exceeded their ME requirements (22 to 36%) in all collections. The differences were significant ($P < 0.01$) for collections 2 and 3 and collection 4 ($P < 0.05$). During collection 1 the difference was just short of significance. The mean ME intakes for the ewes carrying 3 foetuses consistently exceeded ME requirements. Over days 121 to 124 of pregnancy this difference was significant ($P < 0.05$). On all occasions individual non-pregnant, single and triplet bearing ewes consumed in excess of their ME requirements. However there was a tendency for ewes in dental categories D and E to have ME intakes below dental categories A and B.

Table 28 contains details of the blood (ketone bodies, plasma FFA and urea) concentrations. There was no consistent increasing or declining trend for any of these parameters as pregnancy advanced. There were no significant differences in total ketone or FFA concentrations for the non-pregnant ewes but the mean plasma urea (52.3 mg/100 ml) in period 1 was significantly ($P < 0.05$) greater than period 4. The mean ketone body, FFA and urea concentrations over all 4 periods for ewes with a single foetus were not significantly different from the non-pregnant ewes. During period 2 the mean ketone level for single carrying ewes (3.6 mg/100 ml) was significantly ($P < 0.01$) higher than the value (5.0 mg/100 ml) for non-pregnant ewes and also ($P < 0.05$) for single carrying ewes in period 1 (2.5 mg/100 ml). There were no significant differences in FFA and urea concentrations as pregnancy advanced for the single carrying ewes.

The ewes with twin foetuses had significantly ($P < 0.01$) higher ketone body concentrations over all periods (5.3 mg/100 ml) than single carrying ewes (3.8 mg/100 ml) and ($P < 0.001$) non-pregnant ewes (3.4 mg/100 ml). The mean ketone body concentration in period 1 (3.8 mg/100 ml) was significantly less, than that for period 2 (6.1 mg/100 ml) and 3 (5.9 mg/100 ml) at $P < 0.05$ and $P < 0.01$, respectively. The overall mean FFA concentration for twin carrying ewes (402 μ equiv/l) was significantly ($P < 0.01$) higher than for ewes with a single foetus (284 μ equiv/l) and ($P < 0.05$) non-pregnant ewes (245 μ equiv/l). There

Table 28. Expt 9.1 Total ketone body (mg/100 ml), FFA (μ equiv/l) and urea (mg/100 ml) concentrations for ewes in late pregnancy

	Total ketones(mg/100ml)					FFA (μ equiv/l)					Plasma urea (mg/100 ml)				
Period	1	2	3	4	Mean	1	2	3	4	Mean	1	2	3	4	Mean
Barren ewes (3)															
Mean	3.0	3.6	3.8	3.4	3.4	162	383	175	260	245	48.7	52.3	45.9	43.6	47.6
± SE	0.4	0.2	1.0	0.5	0.2	32	66	36	99	50	3.6	1.5	2.9	1.6	1.1
Ewes with single foetus(12)															
Mean	2.5	5.0	3.5	4.5	3.8	240	300	208	365	284	45.8	51.8	47.6	47.6	48.1
± SE	0.2	0.3	0.2	0.5	0.3	31	51	31	49	21	3.2	1.5	2.0	2.6	1.8
Ewes with twin foetuses(17)															
Mean	3.8	6.1	5.9	5.3	5.3	449	348	288	506	402	50.4	54.7	50.8	52.4	51.5
± SE	0.3	0.8	0.5	0.9	0.3	40	34	31	41	28	2.5	2.0	2.1	1.9	1.9
Ewes with three foetuses (4)															
Mean	4.0	5.2	4.8	5.7	4.9	399	393	260	454	377	54.9	55.1	56.8	57.1	56.0
± SE	0.9	1.5	1.1	1.3	1.1	66	84	22	77	40	4.6	2.3	1.1	2.6	1.5

were no significant differences in ketone body, FFA and urea concentrations for ewes carrying either 2 or 3 foetuses. The FFA concentrations (506 μ equiv/l) for ewes with twin foetuses in period 4 were significantly higher than period 3 (288 μ equiv/l) and period 2 (348 μ equiv/l) at $P < 0.001$ and $P < 0.01$, respectively.

The ewes carrying 3 foetuses had higher ketone body and FFA concentrations than either non-pregnant or single carrying ewes but the differences were not significant due to the small numbers of sheep in the non-pregnant and triplet categories. The mean overall plasma urea concentrations for ewes with 3 foetuses were significantly higher in periods 1, 3 and 4 ($P < 0.01$, $P < 0.05$ and $P < 0.01$, respectively) than for non-pregnant ewes. During periods 3 and 4 the mean urea concentrations for ewes with 3 foetuses (56.8 and 57.1 mg/100 ml) were significantly greater ($P < 0.01$ and $P < 0.05$, respectively) than for ewes with a single foetus (47.6 and 47.0 mg/100 ml).

The overall ketone body concentrations were significantly ($P < 0.001$) correlated ($r = 0.84$) with mean FFA values for individual ewes over all periods. The linear regression equation for this relationship was $y = 97x - 104.5$ (SE of $b = \pm 24$) where y = FFA (μ equiv/l) and x = total ketone bodies (mg/100 ml).

Both total ketone bodies and plasma FFA were significantly ($P < 0.001$) correlated with % change in ewe live weight over the experiment ($r = 0.70$ and 0.64, respectively). The relationship (linear) between ketones and % change in ewe live weight was best represented by the equation $y = 3.15 + 0.2831\ x$ (SE of $b \pm 0.13$) where y = total ketones (mg/100 ml) and x = % change in ewe live weight. At ketone levels below about 2.5 mg/100 ml the linear relationship became involved. The linear relationship between FFA and % change in ewe live weight was represented by the equation $y = 249 + 19.6\ x$ (SE of $b \pm 5.1$) where y = FFA (μ equiv/l) and x = % change in ewe live weight. At FFA levels below about 200 μ equiv/l the linear relationship became invalid. Figure 18 illustrates the relationship between these biochemical parameters (ketone bodies and FFA) and percentage change in ewe live weight. The plasma urea concentrations of some ewes were very high (>50 mg/100 ml).

The mean individual feedblock intakes over all 4 collections were significantly ($P < 0.001$) correlated ($r = 0.59$) with mean plasma urea concentration. This relationship (Fig 19) could be represented by a highly significant ($P < 0.001$) linear regression equation, $y = 0.0164\,x + 36.5$ (SE of b $\pm$ 0.0078), where y = plasma urea (mg/100 ml) and x = feedblock intake (g DM).

There were no significant correlations between total litter weight and ketone bodies or FFA. Nor was there any significant relationship between feedblock intake and either total ketones or FFA.

Discussion

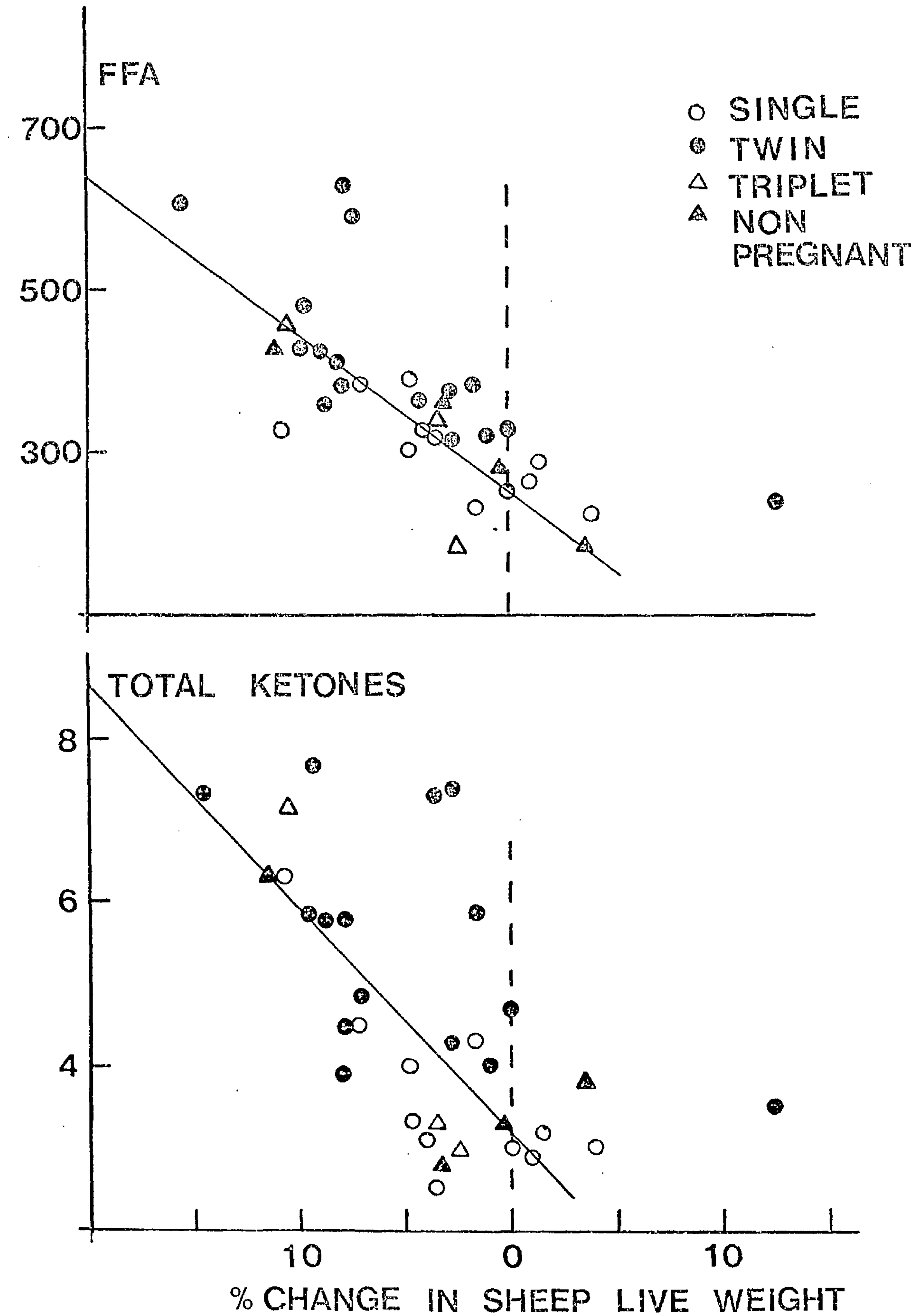
The small numbers of ewes in the non-pregnant and triplet categories limited the confidence which could be placed on comparisons involving these ewes. Therefore in the discussion of the results most emphasis has been placed on the comparisons between ewes with single and twin foetuses.

The results indicated that there did not appear to be any quantitative regulation of feedblock intake according to number of foetuses carried and MAFF et al. (1975) energy requirements. Ewes with only a single foetus in fact consumed slightly more feedblock than ewes with twin foetuses. Nevertheless, several interesting points were revealed by the experiment.

Firstly, the overall mean feedblock consumption and total ME intake particularly for pregnant ewes increased progressively from day 121 to day 138 approximately of pregnancy, i.e. over collections 1 to 3.

Fig.18a Expt 9.1 Relationship between % change in ewe live weight and FFA concentrations (μ equiv/l) measured at 4 samplings during late pregnancy.

Fig.18b Relationship between % change in ewe live weight and total ketone body concentrations (mg/100 ml) measured at 4 samplings during late pregnancy.


FFA
700
500
300
SINGLE
TWIN
TRIPLET
NON PREGNANT
TOTAL KETONES
8
6
4
10
0
10
% CHANGE IN SHEEP LIVE WEIGHT

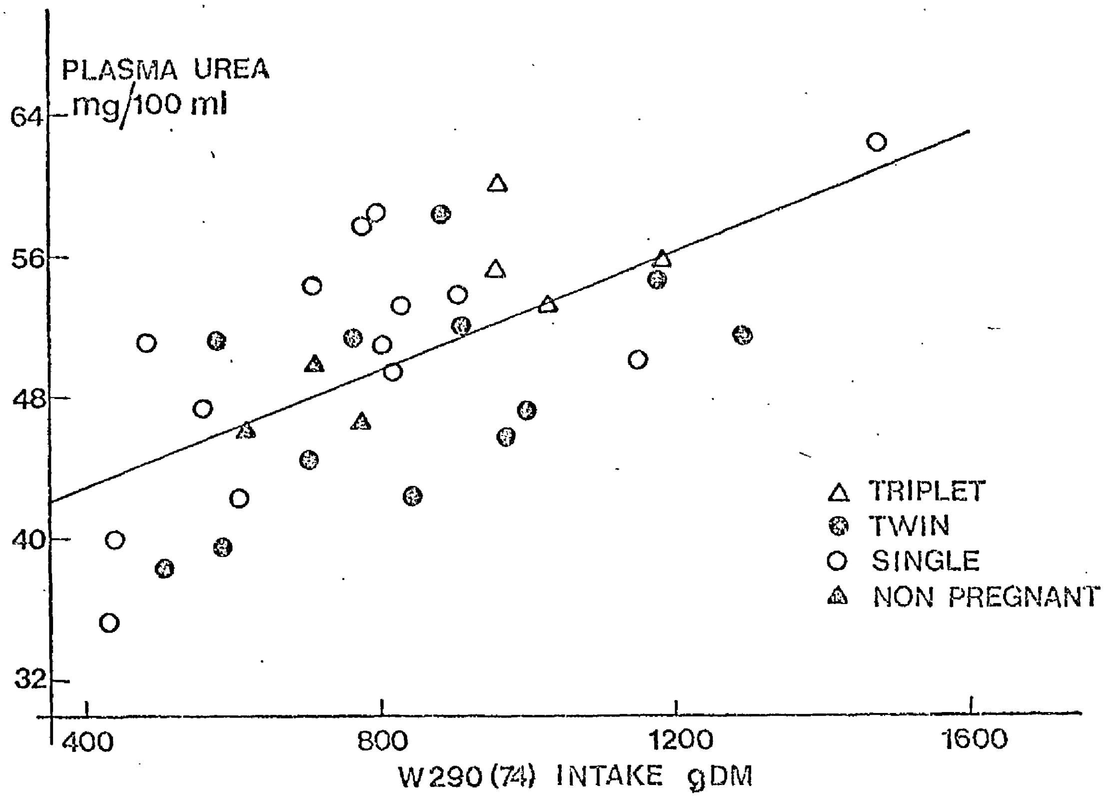


Fig.19 Expt 9.1 The relationship between mean plasma urea concentration (mg/100 ml) over 4 samplings during late pregnancy for non-pregnant, single, twin and triplet carrying ewes and mean W290(74) intake (g DM/head/day) measured over 4 faecal collections.

This may have been due to a training response, but all ewes had received similar feedblocks earlier in pregnancy and should have been well accustomed to the blocks. In the practical situation it is perhaps immaterial why feedblock intake increased in late pregnancy as long as any increase is in accord with the nutritional requirements of the animal. The intake of feedblock may have been rationed slightly for the group E (heavier) ewes, because on some days the feedblock was completely consumed after approximately 20 hours. An immediate introduction of further block material was considered undesirable for reasons unconnected directly with the nutritional status of the sheep, but dictated by the necessity of ensuring manageable faeces for total quantitative collections. It is doubtful if the pattern of feedblock consumption over the experiment would have been markedly altered if this minor rationing of feedblock had not been imposed.

The second point of interest indicated by the pattern of feedblock and therefore total ME intake is that the mean intake of the ewes decreased during the last week or so (collection days 141 to 144) of pregnancy, irrespective of number of foetuses present. This trend was consistent for most individual ewes. Even the non-pregnant ewes showed a slight drop in feedblock intake at this time. Therefore it is perhaps unlikely to be due to physiological causes such as an increased secretion of oestrogen by pregnant ewes, which has been frequently shown to depress appetite at and around parturition. Also the motivation of the ewes to consume grass cubes did not diminish over the last few days of pregnancy.

It was observed in Section 2 that the feedblock intake of housed sheep tended to decline in cold weather and it was suggested that this might be caused by a lower water consumption and a lessened ability to excrete salt consumed from the feedblocks. The W290(74) feedblocks used in this experiment contained only 50 g/kg salt but the level of salt intake attained would be appreciable (30 to 60 g/head). However the decrease in mean block intake did not coincide with a decrease in mean daily temperature and the exact reason for the phenomenon remains unexplained. It would be important to establish whether this drop in feedblock and hence ME intake was infact a consistent feature of providing nutrients in late pregnancy or represented an artifract under the present experimental circumstances. A decrease in feedblock ME intake at or near parturition could have serious consequences, especially in prolific flocks, when considerable reliance is placed on energy from the feedblock.

A third point of interest in Expt 11.1 was that a productive group of ewes was able to consume sufficient ME from a substitute type feedblock, over and above a basal allocation of grass cubes. In fact that level of feedblock intake exhibited by the non-pregnant and single foetus ewes was well in excess of MAFF et al. (1975) requirements and represented a wasteful over consumption, refuting the claim that sheep will regulate their energy intake from feedblocks according to needs.

The failure to detect any regulation of feedblock intake in parallel to energy requirements could possibly have been influenced by the experimental circumstances. For instance, if the allocation of dried grass cubes had been reduced, a greater nutritional stress would have been imposed upon the ewes, which would entail a higher feedblock consumption by some multiparous ewes to alleviate the increased energy deficit. However for practical reasons of faecal consistency, further reliance on feedblocks to provide dietary energy would have probably precipitated scouring and rendered the faeces uncollectable. Also in the practical situation the relatively high cost of energy in feedblocks would make such a situation undesirable, in most cases.

If in this experiment all the ewes were over-consuming feedblock and thereby 'masking' possible energy regulation mechanisms, the choice of a lower intake of relatively unpalatable feedblock could possibly have deterred some of the greedier non-pregnant and some ewes with a single foetus from grossly exceeding their required ME intake. Alternatively some of the multiparous ewes could have been equally deterred and suffered nutritionally as a result. Therefore the most appropriate feedblock to examine possible energy regulation mechanisms is a high intake, substitute-type block.

The adequacy of energy intakes by the ewes was reflected by the lamb birth weights (2.7 to 6.8 kg), satisfactory udder development and subsequent lactation performance. Although, there was some discrepancy between percentage change on live weight over the experiment (all categories of ewes lost weight) and the expected weight change commensurate with the measured ME intakes, this probably reflected the stage of pregnancy when the initial weighings were made. The ewes were first weighed on day 117 of pregnancy which may not have been a true indication of live weight, because of the confounding effect of uterine contents. Therefore the percentage change in ewe live weight was probably overestimated due to the inclusion of some uterine contents in the initial weight. The ME intake of non-pregnant ewes (far in excess of maintenance requirements) was surprisingly not reflected in a substantial live-weight gain.

The blood parameters measured (Total ketone bodies and FFA) were useful indicators of nutritional status. Percentage change in ewe live weight was closely represented by changes in ketone and FFA concentrations. However the absolute ketone levels tended to be rather high (3.4, 3.8, 5.3 and 4.9 mg/100 ml for non-pregnant, ewes with a single foetus, two foetuses or three foetuses, respectively), compared with the values quoted by Peart (1967) with pure Scottish Blackface ewes (well nourished ewes <3 mg/100 ml, moderately undernourished around 3 mg/100 ml and severely undernourished 8 to 10 mg/100 ml during the last 4 weeks of pregnancy).

This may be due to several reasons.

It is possible that the estimated ME values for the dried grass cubes or feedblock were too high and ME intakes were also overestimated. This is very unlikely because the ME values for the respective foods, calculated from the proximate compositions using the equations given in MAFF et al. (1975) agreed closely with the in vivo determinations. Secondly, an overestimation of total ketones may have been due to laboratory contamination with for example acetone. Thirdly, the ME requirements for pregnant Greyface ewes given in MAFF et al. (1975) are too low and the ewes in this experiment were not infact subjected to a generous plane of nutrition. The second reason however appears to be the most plausible, because the FFA values for adequately nourished ewes (245, 284, 402 and 377 μ equiv/l for non-pregnant, ewes with a single foetus, two foetuses or three foetuses, respectively) agree with the values stated by Peart (1967) (400 to 500, 750 and 1200 μ equiv/l for well, moderately and severely undernourished ewes, respectively). In this context the moderately undernourished ewes received sufficient nutrients to almost maintain body weight, in addition to supplying nutritional requirements of the developing foetuses.

A further point of interest to arise from this experiment was the close relationship between plasma urea concentration and feedblock intake (the feedblock contained over 200 g CP/kg DM of which 140 g was CP equivalent from urea) over 4 samplings. It might thus be possible to estimate feedblock intake from plasma urea concentration.

Experiment 9.1 failed to identify a quantitative regulation of feedblock intake according to the energy requirements of ewes during late pregnancy. For the reasons already stated, particularly that all ewes were over-consuming feedblock and greatly exceeded their ME requirements MAFF et al. (1975), in most cases, therefore the experimental circumstances may not have been conducive for the isolation of physiological factors influencing feedblock intake.

Again the importance of dental status in achieving adequate feedblock intakes was clearly shown, the majority of ewes, especially those carrying twins in dental categories D or E (broken mouths) were at a severe disadvantage compared to ewes in categories A or B. This illustrated the inability of ewes to overcome the constraint imposed by an inferior dental status, perhaps by increased licking, even in circumstances when block intake was critical to their nutritional well-being.

One point worthy of cautious optimism in Expt 9.1 was the progressive increase in feedblock intake as pregnancy advanced up to about the final week. Although the exact reasons for this could not be ascertained, such a pattern of intake (the last week apart) is in accord with nutritional requirements.

This phenomenon and many of the other criteria examined here in Expt 9.1 were further examined in the outdoor situation in Expt 9.2.

Expt 9.2. Energy regulation aspects of feedblocks using pregnant and non-pregnant sheep outdoors

Introduction

The results of Expt 9.1 failed to show any quantitative regulation of feedblock intake according to the energy requirements of non-pregnant, single carrying and multiparous sheep. However, nearly all the ewes consumed feedblock material to the extent that ME intakes were usually more than adequate and in some cases wastefully high. The ewes in Expt 9.1 received basal allocations of moderate quality dried grass cubes in excess of their maintenance requirements, thus the challenge made against the ewes to satisfy energy requirements from the block was not too severe and in practice most ewes responded and easily surpassed their required ME intakes. Only ewes with both an inferior dental status (category D or E) and carrying twin foetuses had ME intakes below the MAFF et al. (1975) requirements.

In Expt 9.2 it was intended to impose a greater nutritional stress upon pregnant ewes, over the critical 6-week period before parturition, by reducing the potential ME intake from roughage or other sources and compelling the ewes to rely on feedblock to satisfy their ME requirements. It was hoped that under these circumstances the physiological condition (pregnant or non-pregnant) and/or nutritional requirements (number of foetuses present) would be more likely to result in different and appropriate amounts of feedblock intake. In the practical situation (particularly in hill or upland environments) under-nourishment, particularly of energy is common amongst ewe flocks during late pregnancy. The design of Expt 9.2 was such as to impose a degree of stress that would require a considerable consumption of feedblock by the ewes.

As in Expt 9.1 a feedblock of the substitute-type was chosen, however the Colborn Sheep Energy (CSE) feedblock was used, as it had a slightly greater ME value, than the W290(74) in Expt 9.1.

Expt 9.2 also differed in that the experiment was carried out in an outdoor situation, which imposed a slightly higher energy requirement upon the ewes due to climatic stress factors. Only individuals with a good dental status (category A) were used to remove this complicating constraint on feedblock consumption.

In Expt 9.1 the small numbers of non-pregnant and ewes with 3 foetuses limited the confidence which could be placed on comparisons involving these categories. In the present experiment 8 wether sheep were used with the ewes as non-pregnant control animals.

Materials and Methods

The experiment was carried out in late February and March 1976 and commenced 40 days (day 107 of pregnancy) before the expected time of parturition (3/4/76). Thirty one Greyface (Border Leicester ♂ x Scottish Blackface ♀) ewes, weighing (23/2/76) initially between 48 to 94 kg (Mean 71 kg), were synchronised for oestrus as in Expt 11.1 and allowed access to a paddock of about 4 ha. Eight Greyface wethers of similar mean live weight (66 kg) accompanied the ewes throughout the experiment.

The sheep were given 0.75 kg timothy hay DM (54 g CP, 305 g CF, 17 g EE, 47 g ash and 578 g NFE/kg DM) on a group basis. The DOMD % (53.5 $\pm$ 0.5) of the hay was determined in vivo using 10 wethers in metabolism cages and the ME (8.0 MJ) calculated using the equation MEF = 0.15 x DOMD%. The ME provided by the hay (6 MJ) amounted to about 68% of the mean maintenance requirement of the sheep (8.8 MJ).

Additionally the sheep were given 2 CSE feedblocks in plastic purpose-built containers, which allowed the sheep access to only the top surface of the block. The typical composition of the CSE feedblock is given in Table 1. The ME content of the block (10.7 MJ) was determined according to the technique described on page 74. The feedblocks were weighed daily and new blocks introduced when necessary, to ensure a total quantity of material on offer in excess of the previous 24-hr consumption. The feedblocks contained 9.9 g chromic oxide/kg DM.

All the sheep were equipped for quantitative faecal collection using harnesses and nylon mesh faecal bags. Faeces were collected continuously from day 117 to day 142 of pregnancy in the form of five consecutive 5-day collections. The faecal bags were emptied once daily. The faeces were subsampled according to Method 2 in the Introduction. Individual feedblock intakes during each collection period were calculated from the mean daily recovery of chromic oxide. An approximate estimate of individual hay consumption was made by apportioning faeces according to the DM indigestibility coefficients of the hay and feedblock (0.45 and 0.21, respectively).

On day 4 of each collection period the sheep were weighed and blood samples were obtained for analysis, for total ketone and FFA concentrations.

After lambing (indoors) the ewes were weighed and the number of lambs born and total dry litter weight recorded. The data were analysed in a similar manner to Expt 9.1. The ME requirements for ewes with a single foetus were calculated using the equation $ME = (1.2 + 0.05W)e^{0.0072t}$ and for ewes with 2 foetuses $ME = (0.8 + 0.04W)e^{0.0105t}$, where W = live weight (kg), t = number of days pregnant and e = 2.718 (base of natural logarithm).

In the calculation of percentage change in live weight data for the ewes, the initial live weight used was the mean of the weight on 21/11/75 and 23/2/76. It was hoped that this would reflect true body weight without the complication of uterine contents.

Results

During Expt 9.2 the weather was generally very wet with several days of heavy, driving rain causing the ewes to seek shelter. The mean daily temperature varied between -1 to 5°C.

One ewe consistently produced faeces containing no chromic oxide and thus consumed no feedblock. This animal had a very low estimated ME intake (6.8 MJ/day over the experimental period) and was not included in the analysis of the results. However a viable lamb was produced weighing 4.6 kg. No reason could be given to explain this refusal to consume feedblock (a full compliment of incisor teeth was present).

A second ewe became progressively weaker as pregnancy advanced and eventually showed symptoms of pregnancy toxaemia, characterised by total ketone and FFA concentrations in the blood of 39.2 mg/100 mls and

1345 μ equiv/l, respectively, 10 days before lambing. At this time the ewe was removed from the experiment and recovered after producing 2 dead lambs (7.3 kg combined weight). Her feedblock consumption had decreased from 450 g to 140 g/day over collections 1 to 4 and the total ME intake form 9.0 to 5.0 MJ. The data from this ewe were included in the results analysis when possible.

Nearly all the pregnant sheep lambed within a 5-day period. Twenty of the ewes produced twins (mean combined birth wt. = 8.7 $\pm$ 0.3 kg, range 5.5 to 11.4 kg), 7 ewes produced single lambs (mean birth wt. = 5.3 $\pm$ 0.3, range 4.6 to 6.4 kg) and 4 ewes were non-pregnant (12 non-pregnant sheep in total).

The live weights, estimated hay and feedblock intakes for non-pregnant, single and twin-bearing sheep are given in Table 29, for the various collection periods. Over the total experiment (40 days) the mean intake of feedblock measured by daily weighing was 473 $\pm$ 28 g DM/head. Feedblock intake for all sheep increased by 77% over collections 1 to 5. Although the mean feedblock intakes of most sheep increased progressively during collections 1 to 4, the largest increase in mean feedblock consumption occurred during collection 5, in the week before lambing. The mean feedblock intake during collection 5 (777 g DM/head) was significantly greater ($P < 0.01$) than all other collections.
The percentage increases in feedblock intake over the experimental period were (collections 1 to 5) 126, 46 and 40% for non-pregnant, single and twin-bearing sheep, respectively. The mean intake during collection 5 was significantly increased ($P < 0.001$ for non-pregnant and $P < 0.01$ for twin-bearing sheep) over collection 1, the difference was non significant for single-bearing sheep due to the small number in this category. The coefficients of individual variation in feedblock intake (42 to 54%) for all 39 sheep were in the same order as Expt 3.2, when the CSE feedblock was given to a group of 16 ewes. The coefficients

Table 29 Expt 9.2 Mean live weights (kg), daily feedblock and hay DM intakes (g) for sheep outdoors

Period	1	2	3	4	5	Mean over all 5 periods
Days of pregnancy	(119-123)	(124-128)	(129-133)	(134-138)	(139-143)	
Feedblock (g)						
Non-pregnant (12)‡	341 (67)+	379 (69)	512 (44)	543 (30)	769 (40)	509 (42)
Single (6)	482 (54)	469 (60)	550 (54)	459 (63)	702 (51)	532 (49)
Twin (20)	504 (38)	526 (41)	609 (37)	610 (37)	835 (41)	617 (37)
All sheep (38)	438 (51)	459 (54)	555 (47)	551 (42)	773 (44)	555
Hay intake (g)						
Non-pregnant	756 (26)	805 (19)	864 (17)	799 (21)	764 (20)	798 (18)
Single	933 (22)	847 (13)	846 (21)	876 (32)	896 (33)	880 (20)
Twin	808 (29)	825 (27)	869 (26)	807 (32)	774 (30)	817 (27)
All sheep	811 (27)	822 (28)	864 (22)	815 (28)	790 (28)	820
Live weight (kg)						Post Lambing
Non-pregnant	68 ± 3.0	66 ± 3.1	66 ± 2.8	66 ± 2.9	68 ± 3.0	-
Single	68 ± 1.6	69 ± 2.3	70 ± 2.4	69 ± 2.7	71 ± 2.7	57 ± 2.4
Twin	70 ± 1.7	72 ± 1.6	72 ± 1.7	73 ± 1.8	74 ± 1.9	57 ± 1.7

‡ Includes 8 wether sheep

+ (CV%)

of variation for feedblock intake were consistently greater than for hay intake.

There were no significant differences in mean feedblock or hay intakes, irrespective of whether one or two foetuses were present. Only on one occasion (collection 1, days 119 to 123 of pregnancy), was the mean feedblock intake of twin-bearing ewes (504 g/head) significantly greater than that for non-pregnant sheep (341 g/head). Over the total period when feedblock intakes were measured the mean intake for twin-bearing ewes (617 g/head) was 21 and 17% in excess of the intakes for non-pregnant (509 g/head) single-bearing (532 g/head) sheep, respectively.

The single-bearing ewes consumed a mean 10 and 8% more hay DM than non-pregnant and twin-bearing sheep, respectively, over the whole experiment. The differences in hay intake between the various categories did not reach significance in any of the collection periods.

The mean percentage changes in sheep live weights for non-pregnant, single and twin-bearing sheep were zero, -20 ± 2.7 and $-19 \pm 1.5\%$, respectively. For the pregnant ewes this was a reflection of change in net body weight $\left(\frac{\text{Initial wt - Post lambing wt}}{\text{initial wt}}\right)$. The initial live weight was taken to be the mean of the ewes non-pregnant weight (11/11/75) and the weight on the day 105 of pregnancy (23/2/76). The absolute live weight of the pregnant sheep remained constant as pregnancy advanced, indicating a loss in net body weight.

There were no significant correlations between either feedblock or hay intakes with percentage change in live weight of pregnant and all sheep combined. The total litter weight of twin-bearing ewes was significantly (P 0.05) correlated ($r = 0.55$) with CSE intake. There were no significant correlations between hay intake and total litter weight for ditocus ewes alone and when the pregnant ewes were combined.

The total ME intakes and calculated ME requirements for non-pregnant, single and twin-bearing sheep during the various collection periods are given in Table 30. The CSE feedblock supplied 46, 45 and 50% of the total ME intake for non-pregnant, single and twin-bearing sheep, respectively. The non-pregnant sheep consistently exceeded their required ME intakes (37% over the whole experiment), the differences in mean ME intake (11.9 MJ/head) and requirements (8.6 MJ/head) were significant ($P < 0.001$) in periods 3, 4 and 5 and significant ($P < 0.01$) overall. The number of individual non-pregnant sheep failing to exceed their ME requirements were 5 and 3 (of a total of 12) in collections 1 and 2, respectively.

The single-bearing ewes consumed a mean 5% more ME (12.7 MJ/head) than their requirements (12.1 MJ/head), overall collections. The mean ME intake consistently exceeded the required value but the differences did not reach significance. Two of the 6 ewes with a single foetus consumed insufficient ME from either block of hay to meet their requirements in any collection period.

The mean daily ME intakes of twin-bearing ewes (13.2 MJ/head) were 10% below the required amount over the total experimental period (14.6 MJ/head). The difference was not significant. Only 4 ewes consistently exceeded their ME requirements in every collection period. Nine ewes, including the individual which developed clinical symptoms of pregnancy toxaemia, failed to exceed their required ME intakes in any collection period. The total ME intake by twin-bearing ewes during period 5 (15.2 MJ/head/day) was significantly ($P < 0.01$ for collections 1 and 2 and $P < 0.05$ for collections 3 and 4) greater than their intake during previous collections.

There were no significant differences in the ME intakes from feedblock, hay or total ME, irrespective of number of foetuses present. There was no significant correlation between total ME intake (mean over all collections) and litter weight for single-bearing ewes. The total litter weight of twin-bearing ewes was significantly ($P < 0.001$)

Table 30 Expt 9.2 Mean ME intakes (MJ/day) and calculated ME requirements (MJ) for sheep in late pregnancy outdoors

Period	1	2	3	4	5		Level of significance between actual and required ME intake
Days	119-123	124-128	129-133	134-138	139-143	Mean	
Non-pregnant sheep (12)							
ME from Block	3.7±0.7	4.1±0.8	5.5±0.7	5.8±0.5	8.2±0.9	5.5±0.7	
ME from Hay	6.0±0.5	6.4±0.4	6.9±0.3	6.4±0.4	6.0±0.4	6.4±0.3	
Total ME intake	9.7±1.0	10.5±1.0	12.4±0.8	12.2±0.7	14.2±1.2	11.9±0.8	
ME requirement	8.6	8.6	8.6	8.6	8.6	8.6±0.3	P <0.01
Single lambs (6)							
ME from Block	5.2±1.1	5.0±1.2	5.9±1.3	4.9±1.3	7.5±1.6	5.7±1.1	
ME from Hay	7.4±0.6	6.8±0.3	6.7±0.5	6.9±0.9	7.2±0.9	7.0±0.5	
Total ME intake	12.7±1.5	11.8±1.3	12.6±1.8	11.8±1.4	14.7±1.7	12.7±1.6	
ME requirement	11.1±0.5	11.6±0.5	12.1±0.5	12.5±0.5	12.9±0.6	12.1±0.5	NS
Twin lambs (2)							
ME from Block	5.4±0.5	5.6±0.5	6.5±0.6	6.5±0.5	8.9±0.8	6.6±0.5	
ME from Hay	6.5±0.4	6.6±0.4	7.0±0.4	6.6±0.5	6.3±0.4	6.6±0.4	
Total ME intake	11.9±0.7	12.2±0.7	13.5±0.9	13.1±0.9	15.2±1.2	13.2±0.8	
ME requirement	13.1±0.2	13.8±0.3	14.6±0.3	15.4±0.3	16.3±0.3	14.6±0.3	NS

correlated ($r = 0.68$) with total ME intake, Fig 20.

The percentage change in live weight for all sheep was significantly ($P < 0.001$) correlated with the percentage difference between actual and required ME intake. This relationship is described in Fig 21 and a linear regression equation ($y = 1.84x + 29.6$, SE of b $= \pm 0.79$, where y = % difference in actual and required ME intake and x = % change in sheep live weight) was fitted to the data. This relationship was significant ($P < 0.001$). Several twin-bearing ewes and 2 single-bearing ewes exceeded their calculated ME requirements (mean of 5 collections), yet still lost more than 20% of their initial live weight. Other pregnant ewes consuming just below their ME requirements had live weight losses of the same order. The majority of the non-pregnant sheep gained or maintained live weight.

Table 31 presents the mean total ketone body and FFA data for the sheep in the various collection periods. There was no consistent change in either parameter as pregnancy advanced. The twin-bearing ewes had a slightly (but not significantly) higher mean ketone body concentration over all 5 samplings (8.8 mg/100 ml) than either single-bearing or non-pregnant sheep (8.1 and 6.0 mg/100 mls, respectively). The mean overall plasma FFA concentration (718 μ equiv/l) for twin-bearing ewes was significantly ($P < 0.05$) higher than the value for non-pregnant sheep (450 μ equiv/l) but not significantly greater than the concentration for single-bearing ewes (655 μ equiv/l).

There was a significant ($P < 0.001$) correlation $r = 0.68$, between total ketone body and FFA concentrations (means of 5 samplings). This was best represented by a significant ($P < 0.001$) linear regression line $y = 55.9x + 196$, SE of b $= \pm 20.3$, where y = FFA (μ equiv/l) and x = total ketones (mg/100 ml).

There were no significant correlations between total ketone body and FFA concentrations (means over all samplings) and either feedblock,

Fig.20a Expt 9.2 Relationship between litter weight (kg) and total ME intake (MJ) from both CSE feedblock and hay.

Fig.20b Expt 9.2 Relationship between litter weight (kg) and mean CSE feedblock intake (g DM/head/day) measured over the last 30 days of pregnancy.

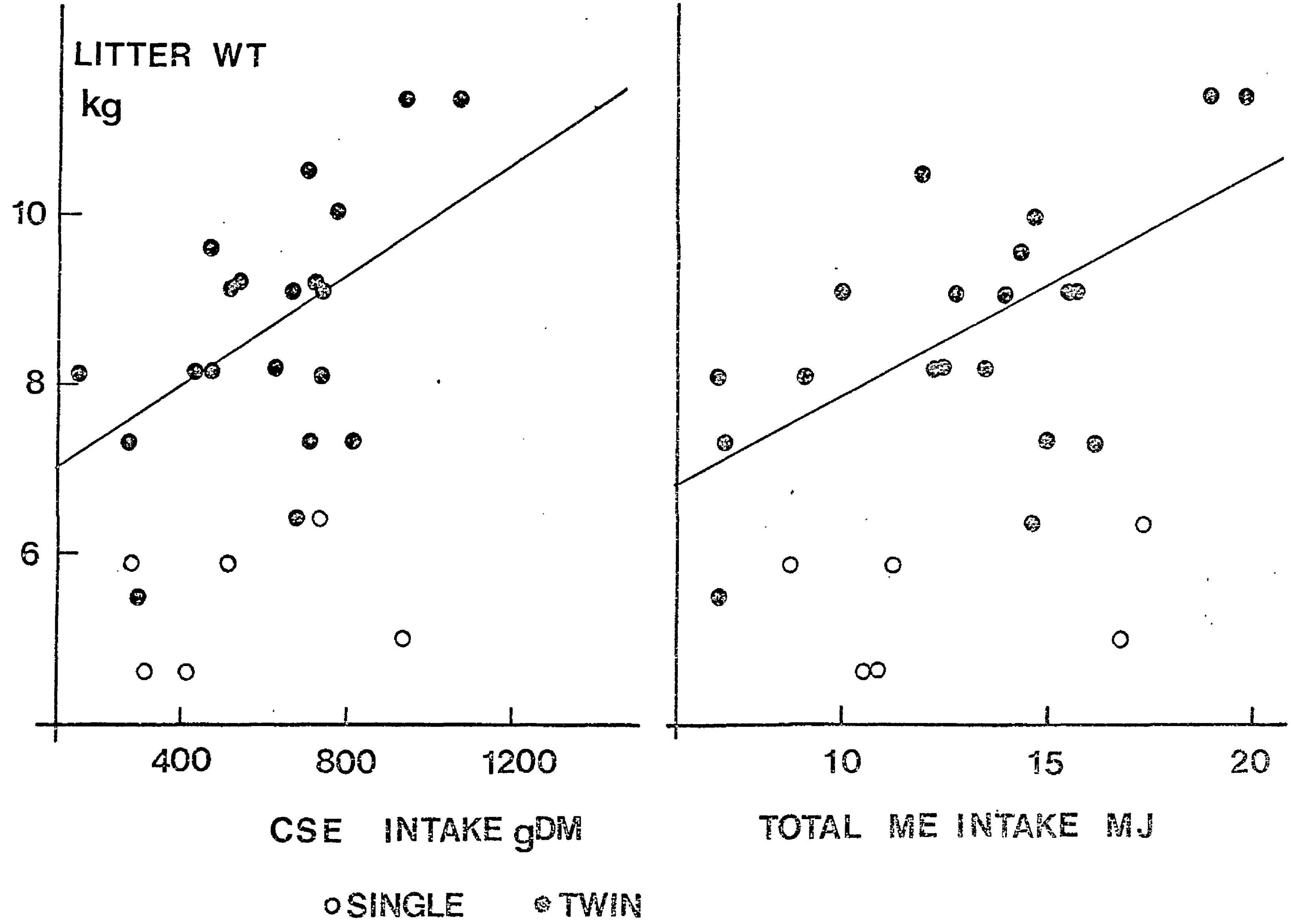

LITTER WT
kg
10
8
6
400
800
1200
CSE INTAKE gDM
10
15
20
TOTAL ME INTAKE MJ
SINGLE
TWIN

Fig.21 Expt 9.2 Relationship between % change in sheep live weight and ME intake (MJ) expressed as a % of ME requirement for individual sheep either non-pregnant, single or twin bearing during last 35 days of pregnancy.

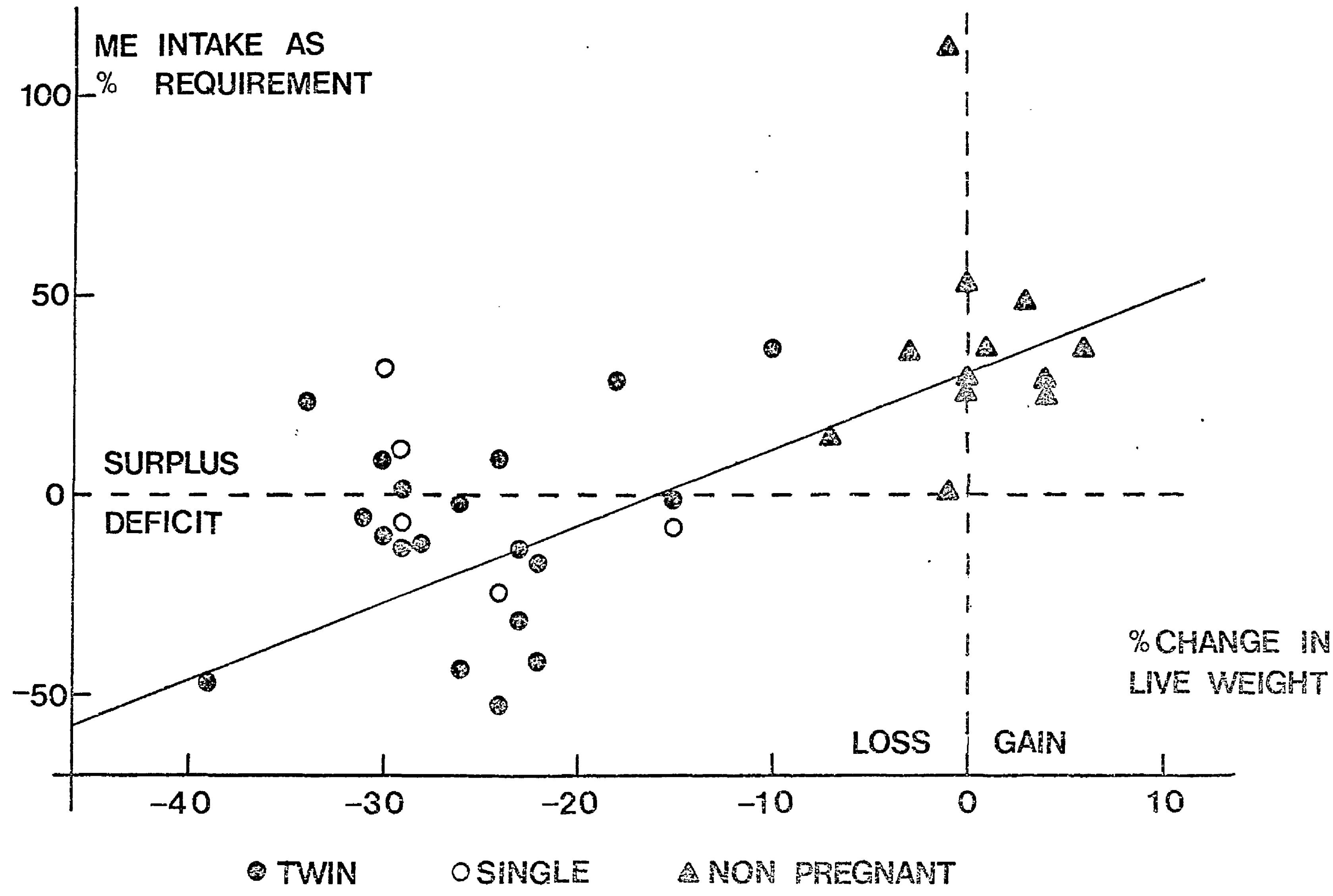

ME INTAKE AS
% REQUIREMENT
100
50
0
-50
SURPLUS
DEFICIT
LOSS
GAIN
% CHANGE IN
LIVE WEIGHT
-40
-30
-20
-10
0
10
TWIN
SINGLE
NON PREGNANT

Table 31 Expt 9.2. Mean ketone body level (mg/100 ml) and FFA and (μ equiv/l) for sheep

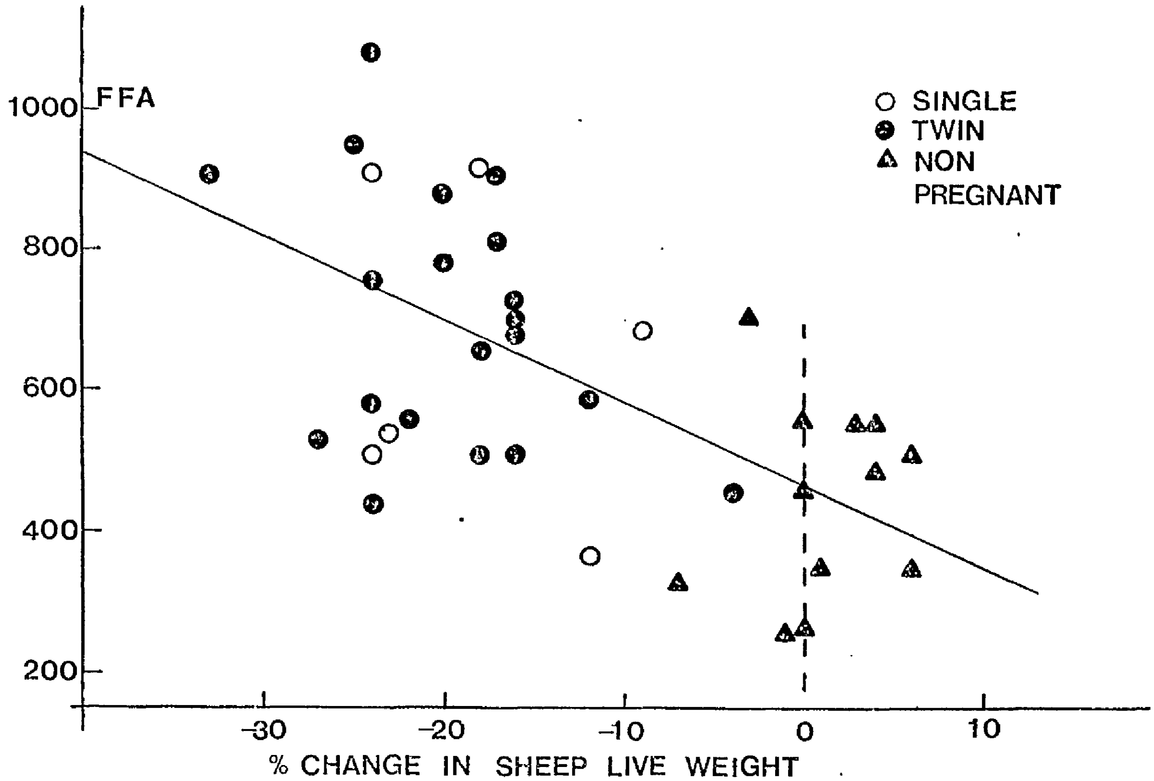
Collection	1	2	3	4	5	Mean	
Days	119-123	124-128	129-133	134-138	139-143		
Total ketone bodies (mg/100 mls)							
Non-pregnant (12)	4.7±0.6	6.1±0.7	6.3±0.6	5.9±0.8	-	6.0±0.3	
Single (6)	6.4±1.0	5.3±0.4	8.3±1.1	12.1±4.3	8.4±1.4	8.1±1.1	
Twin (20)	9.3±0.9	7.8±0.7	7.8±0.7	12.1±2.3	6.8±0.7	8.8±0.6	NS
Plasma FFA (μ equiv/l)							
Non-pregnant (12)	477±60	361±22	544±65	327±32	-	450±41	
Single (6)	622±119	470±100	892±101	576±92	715±155	655±91	
Twin (20)	840±74	532±45	815±65	641±55	762±27	718±43	

hay or total ME intake for all sheep. The percentage difference between actual and required ME intakes for all sheep was significantly ($P < 0.001$) correlated ($r = -0.57$) with mean ketone body concentration. A significant ($P < 0.001$) linear regression line (Fig 22) fitted the data ($y = 7.32x - 62$, SE of $b = \pm 3.45$, where y = % difference in actual and required ME intakes and x = total ketone body concentration mg/100 ml).

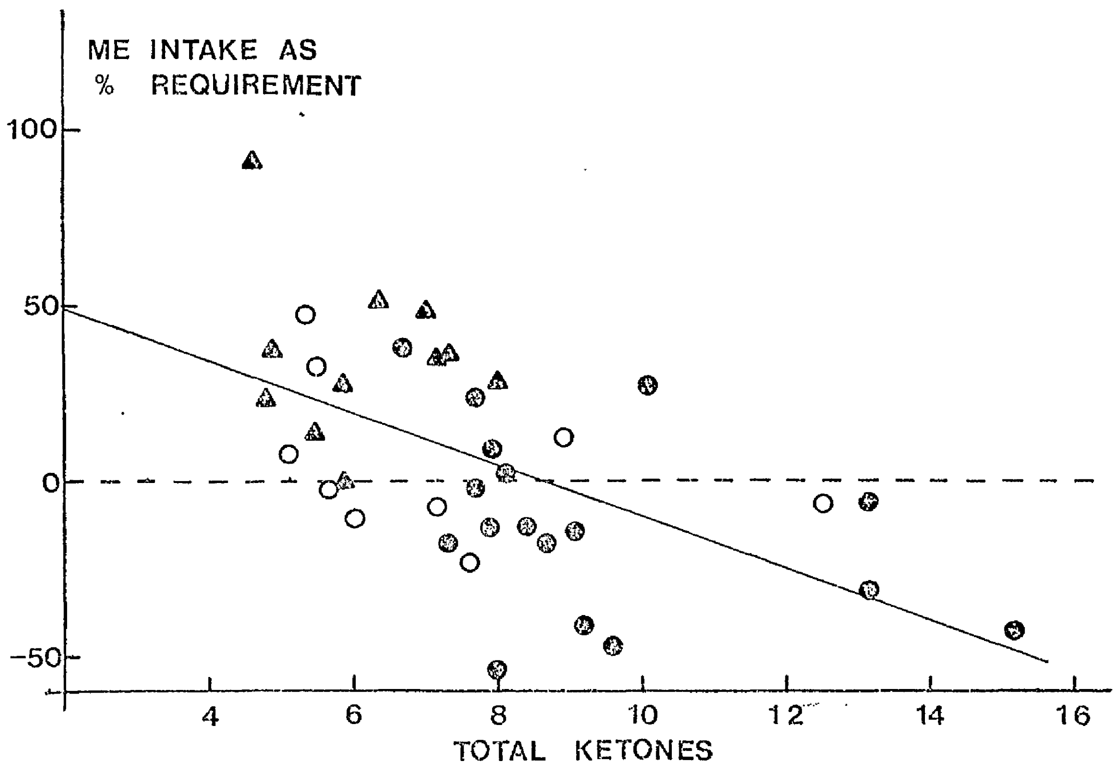
Similarly the percentage difference between actual and required ME intakes for all sheep was significantly ($P < 0.001$) correlated ($r = -0.67$) with mean FFA concentration. This relationship was best represented by a linear regression equation ($y = 0.1046x - 3.2$, SE of $b = \pm 0.039$, where y = % difference in actual and required ME intakes and

Fig.22a Expt 9.2 Relationship between % change in sheep live weight and mean FFA (μ equiv/l) concentrations over 5 samplings during late pregnancy for non-pregnant, single and twin bearing individuals.

Fig.22b Relationship between total ketone body (mg/100 ml) concentrations and ME intake (MJ) expressed as a % of ME requirement during late pregnancy.



FFA
1000
800
600
400
200
SINGLE
TWIN
NON PREGNANT
-30
-20
-10
0
10
% CHANGE IN SHEEP LIVE WEIGHT



ME INTAKE AS % REQUIREMENT
100
50
0
-50
4
6
8
10
12
14
16
TOTAL KETONES

x = FFA μ equiv/l.

Only for ewes bearing twins was the feedblock intake significantly ($P < 0.05$) correlated with both total ketone and FFA concentrations ($r = -0.51$ and -0.57, respectively).

The percentage change in sheep live weight was significantly ($P < 0.001$ and $P < 0.01$) correlated ($r = -0.89$ and -0.46) with the mean FFA (Fig 22) and ketone body concentrations, respectively, over 5 samplings. These relationships were represented by the following linear regression equations. Where x = % change in sheep live weight

a) $y = 11.3x + 470$, SE of $b = \pm 5.29$ ($P < 0.001$), y = FFA (μ equiv/l)

b) $y = 0.11x + 9.2$, SE of $b = \pm 0.08$ ($P < 0.01$), y = ketones (mg/100ml).

There were no significant correlations between litter weights and either total ketone or FFA concentrations.

Discussion

In this experiment the computation of individual hay and therefore total ME intakes relied upon faecal apportionment, according to the indigestibilities of the CSE feedblock and hay. The quantity of DM consumed from the pasture was discounted as being negligible compared to the other components. The limitations of faecal apportionment in estimating individual hay intakes have been discussed in detail in Expts 1 and 2. No attempt was made here to quantify any of the likely interactions between the two dietary components, such as an increase in hay digestibility due to the elimination of a possible nitrogen deficiency. Therefore the hay and total ME intakes are approximations only. The mean daily hay DM intake (820 g/head) over the experimental period was 9% greater than the amount allocated (750 g/head). This discrepancy may reflect the small amount of DM consumed from the pasture or errors inherent in the technique.

There was a tendency for the feedblock intakes of all sheep to increase (77% over all) as the experiment progressed. This increase was particularly apparent during period 5 (days 139 to 143 of pregnancy), which is the converse of Expt 11.1, when the intakes of W290(74) feedblock decreased in the 4 to 5-day period prior to parturition. It is perhaps very likely that the gradual increase in feedblock measured here and during the first 3 collections of Expt 11.1 represents a training effect, rather than a physiologically induced stimulus from the increasing demands of gestation. The non-pregnant sheep in fact increased their feedblock intakes most (126%) compared with single (46%) and twin-bearing ewes (40%). The increase in feedblock intake for all sheep was aided by the instability of the block containers, which were frequently pushed over in the later stages of the experiment. This offered an increased surface area of block material available to the sheep and may have applications in practice. For example, if feedblocks are initially given to the animals in containers, when an increased consumption is desired, such as in the last 2 to 3 weeks before parturition it would be reasonable to expect this to occur if the blocks were offered without protection.

The experiment was successful in that a large proportion of the pregnant ewes were suffering moderate to severe nutritional stress, probably exacerbated by the very wet weather conditions. As in Expt 11.1 the concentrations of total ketone bodies and FFA in the blood were good indicators of nutritional status both in terms of sufficiency of ME intake and catabolism of body tissues. Again the mean ketone body concentrations appeared to be higher than those measured by other workers, e.g. Peart (1967) found that Scottish Blackface ewes receiving nutrients to almost maintain maternal body weight (moderately undernourished) during late pregnancy had ketone and FFA levels of about 3 mg/100 ml and

750 μ equiv/l, respectively. The mean total ketone body concentration of the pregnant ewes during period 5 was 12.1 mg/100 ml which (adopting the criteria of Peart, (1967) meant that the ewes were severely undernourished, although in practice, on average they maintained absolute maternal weight.

It is possible, but unlikely, that the ketone body levels measured here reflect the absolute severity of undernourishment, because of the equally high concentrations for non-pregnant sheep (mean = 6.0 mg/100 ml over all collections) and the similarity between the FFA levels measured here and by Peart (1967) and nutritional status. The non-pregnant sheep in this experiment had a mean FFA concentration over 5 samplings of 450 μ equiv/l and maintained live weight. Using the criteria of Peart (1967), FFA levels of 400 to 500 μ equiv/l are indicative of well nourished sheep. Therefore although Scottish Blackface ewes are usually single-bearing the likely explanation of the high ketone body levels measured here is an analytical error. Nevertheless they are still very useful biochemical indicators of relative nutritional status, exemplified by their close correlation with FFA concentrations.

The results of the present study agreed with Expt 11.1 in that there was little evidence to suggest a quantitative regulation of energy intake from the feedblock to balance the energy requirements of non-pregnant, single and twin-bearing sheep. Although the twin-bearing ewes consumed slightly more feedblock (21 and 17% respectively) than non-pregnant and single-bearing sheep, there was a large variation in feedblock intake between individual ewes. There was no difference in feedblock intake between the single-bearing and non-pregnant categories, but the small number of sheep in the former group limited the confidence which could be placed upon comparisons involving single-bearing ewes.

Many of the pregnant ewes consumed insufficient feedblock and/or hay to exceed their ME requirements and consequently were undernourished.

This was characterised in the extreme case by the development of clinical pregnancy toxaemia in one twin-bearing ewe which eventually produced dead lambs. Although the MAFF et al. (1975) ME requirement in most periods and overall (14.6 MJ) exceeded the mean ME intakes (13.2 MJ over all) by only about 10%, 25% of the twin-bearing ewes had ME intakes which were between 30 and 55% below their individual requirements (Fig 21). Conversely, the total ME intakes of 11 of the non-pregnant sheep were consistently greater than their ME maintenance requirements (15 to 110%), largely due to excessive ME intake from feedblock. This emphasises two points, firstly that the MAFF et al. (1975) allowances for ME can only be guide lines and apply only to the 'average' animal. For example all the twin-bearing ewes lost net body weight, which is consistent with their mean ME intakes being below the suggested requirements. Several twin-bearing ewes consistently exceeded their ME requirements yet still lost net body weight, therefore there is considerable variation about the mean for ME requirements of pregnant ewes. This is not surprising because there may be a two-fold difference in total litter weight for twin-bearing ewes of similar live weights and ME requirements. It is perhaps therefore an over-simplification to expect individual sheep to consume sufficient ME to balance a suggested requirement, for an average sheep of the same live weight.

Secondly, even if the total ME allocated to a group of animals is reasonably accurate, the individual variation in food/ME intake in competitive situations, even taking into consideration the safety margins allowed, ensures imprecise nutrition and makes the total nutrient allocation of academic interest only. For example, the mean daily ME intake for all sheep during collection 5 was about 14.6 MJ/head, (773 g of CSE = 8.3 MJ plus 790 g of hay = 6.3 MJ) or 570 MJ in total. The MAFF et al. (1975) ME requirements for non-pregnant, single and twin-bearing ewes at that time were 8.6, 12.9 and 16.3 MJ, respectively. If a hypothetical energy regulatory mechanism had been in existence the 12 non-pregnant, 6 single and 20 twin-bearing sheep would have consumed 103, 77 and 326 MJ, respectively, or 507 MJ in total, leaving a surplus of 63 MJ and all sheep supposedly with adequate nourishment. Instead, the non-pregnant sheep consumed 65% more (14.2 MJ) than required, the single-bearing ewes consumed 14% more than required and the twin-bearing sheep on average consumed 7% less than required. Similar examples could be drawn on other collection periods.

Even when a large proportion of the total energy intake of sheep (45 to 50%) is taken from a 'self-help' source, there is no evidence to support the claim that animals will regulate energy intakes according to needs. In Section 1 where individual variation in food intake was studied in detail for 'self-fed' and 'hand-fed' animals, a similar large degree of individual variation in nutrient intake was invariably found, although this tended to be lower for the 'hand-fed' system. However no attempt was made there to outline the practical consequences of this unequal distribution. The results of Expts 9.1 and particularly 9.2 allowed this to be made. Apart from the clinical case of pregnancy toxaemia already described, several of the twin-bearing ewes were suffering from agalactca at the onset of lactation due to undernourishment. Even though the total amount of ME consumed was ample during the experimental period, the distribution between sheep was unequal and not related to true need.

One encouraging feature of Expts 9.1 and 9.2 was that there was a progressive increase in feedblock intake as pregnancy proceeded and suggests possible applications in practice, particularly if combined with the careful use of containers.

C The effectiveness of feedblocks as carriers of supplementary magnesium

Introduction

In the introduction to this section some of the likely difficulties concerned with the use of feedblocks as magnesium carriers, to act as a prophylactic against ruminant hypomagnesaemic tetany were described. Principally these were the individual variation in intake, as measured in Section 1 and fluctuations in total group intake with the factors outlined in Section 2. In particular, the observations made in Section 2 and the results of Part A of this section, suggest that the intake of feedblock is likely to be very low at times when alternative high quality nutrients such as spring grass are also available. This may be incompatible with the use of feedblocks as a magnesium carrier at such times.

Several feedblock manufacturers claim to have overcome this problem by producing what are supposedly very attractive and palatable feedblocks, specially designed for use during the critical period of transfer to grazing in the spring, when acute hypomagnesaemic tetany is most likely to occur. One of the objectives of Part C of this section was to evaluate the effectiveness of these feedblocks with both cattle and sheep. In several of the experiments a control treatment where the animals received similar amounts of supplementary magnesium as concentrate cubes in troughs was included.

In many situations outwintered cattle and sheep may be given feedblocks for a period of several months. In these cases the use of magnesium containing feedblocks may be more effective, because there is a gradual provision of better quality nutrients as grass growth occurs, rather than the drastic change when housed ruminants are turned out. It may be that feedblock intake declines much more slowly under these conditions. In some of the experiments the use of magnesium carrying feedblocks in the spring period for outwintered sheep was examined.

In parts A and B of this Section there appeared to be little evidence to substantiate the claim that ruminants will consume feedblock nutrients according to their nutritional requirements. The emphasis in these experiments was placed on possible energy and protein regulatory mechanisms. In Part C the relationship between physiological condition and magnesium intake during the critical spring turn-out period was studied using both ewes and cows, in an attempt to relate magnesium intake to need.

In some respects a feedblock containing appreciable amounts of magnesium (75 to 100 g MgO/kg DM) can be likened to a "Free Access mineral" in a block form, in that the principles and claimed advantages concerned with feeding one apply equally to the other. In both systems it is possible for the animals to consume ingredients 'little and often,' unlike the provision of supplementary magnesium in concentrates given in troughs. Frequency of magnesium intake may be far more important than absolute amount given, Ritchie and Hemingway (1963). Secondly, the animals have the opportunity (slightly less with feedblock because of the hardness and other intake constraints) to consume nutrients according to their needs.

The practice of giving free access minerals to ruminants has been the subject of three reviews, Coppock (1970) for dairy cows; Gordon (1970) and Pamp, Goodrick and Meiske (1976), for ruminants in general. Coppock (1970) concluded that the assumption that need and intake of a mineral supplement are directly related seemed unwarranted by the data available. The consumption of calcium/phosphorus mineral supplements by cattle appeared to be related to taste rather than need.

Nevertheless, the early observations of workers such as Green (1925) are frequently cited as examples of so called 'nutritional wisdom.' He made the statement that 'It seems a remarkable manifestation of instinct or intelligence that physiological deficiency in cattle should be reflected by a specific craving for bones, the only accidentally available source of phosphorus capable of relieving this craving.' Other examples of 'nutritional wisdom' have been produced by Hardison, Reid, Martin and Woofolk (1954). These workers reported that the diet selected by grazing steers was higher in crude protein, ether extract and mineral matter and lower in crude fibre than the whole herbage available for consumption. In addition all the proximate constituents of the grazed herbage were of higher digestibility than those of clipped herbage from the same source given to stall fed steers.

Scott and Quint (1946) and Scott, Verney and Morrisey (1950) reported that a relationship between dietary selection and physiological need may arise through two mechanisms. Firstly, the animal may learn that a given choice results in a feeling of well-being and therefore prefer it (learned appetite). Secondly, there may be a direct relationship between appetite and need, where need causes an instinctive desire for a given nutrient (true appetite response).

The only dietary nutrient which has been unequivocally shown to be consumed by ruminants according to need is salt. Denton and Sabine (1961) found a large increase in appetite for sodium in sheep fitted with parotid duct fistulae. The intake of many of their animals was adequate to maintain normal sodium balance. Even when the concentrations of the sodium solution were varied, or if access was only allowed for a short period each day, the sheep varied the volume of salt solution drunk and consumed sufficient sodium to balance the loss from the fistula and correct the sodium deficit. In his review of salt appetite, Denton (1967), stated that "The ability to taste salt is inherited in all mammals and there is a universal liking for salt - a primitive attraction to it. No instance of a definite aversion to salt has been found."

In one experiment, Gordon and Tribe (1951) the inability of 8 pregnant (Cheviot) ewes given their diet in its constituent parts (water, mineral salt licks, chopped hay, yellow maize or crushed oats and either linseed cake or white fish meal) to select a balanced diet was demonstrated in a catastrophic manner. Food intake fell a few weeks before lambing and three ewes died of pregnancy toxaemia. All lambs born were weak, some did not suckle and over half died. Only one ewe produced a satisfactory milk supply but even this animal produced small lambs.

There appears to be only one report where feedblocks or licks on a 'free-access' basis have been studied as magnesium carriers. Todd, Scally and Ingram (1966) in two experiments provided the only source of magnesium as an equal part molasses-magnesia mixture in 'free-access' tubs. The mixture appeared to be quite palatable to the cows, even in the spring and they went frequently to the tubs. During a 3-day period the cows were watched for continuous periods of 4 hours and on each occasion 20 of the 23 cows visited the tub. Only one cow was not seen at the tubs on any of these occasions. The average daily intake of calcined magnesite was 53 g/head and the cows maintained serum magnesium levels.

In a second experiment, carried out during the autumn, the cows were observed for a 10-hour period on 2 days and on each occasion only 2 were not observed to visit the tubs. Only one cow consistently failed to consume enough of the mixture to maintain a normal serum magnesium level and she developed clinical tetany. The mean intake of calcined magnesite was 42 g/head. The authors stated that the supplements were effective because 16 out of the 28 cows were severely hypomagnesaemic when the supplements were withdrawn.

Horvath, Dozza, Kidder, Warren, Bhatt and Croushore (1967) emphasised that cattle housed or yarded will consume magnesium in a variety of supplements but the same supplements may not be consumed by the same animals when they are turned out for spring grazing.

Gordon (1970) stated that although ruminants show an ability to select their own diets at pasture and in the case of sodium deficiency, other mineral needs such as cobalt, magnesium and phosphorus may not come within the animals scope of control even when readily available.

A series of factors which may affect the intake of 'free access' mineral mixtures have been proposed by Coppock (1970) and Cunha, Shirley, Champman, Ammerman, Davis, Kir and Hentes (1964). These may equally apply for minerals contained in feedblocks together with the many other factors described in Section 2, as being important in determining feedblock intakes.

a) Soil fertility; high fertility results in less consumption.

b) Type of forage consumed; greater intakes occur on unimproved than on improved pastures.

c) Type and amount of other supplementary feeding.

d) Requirements for the mineral elements such as gestation or lactation.

e) Mineral content of drinking water.

f) Palatability. (Taste).

g) Availability of mineral mixture.

h) Accessibility.

i) pH - cattle prefer an acid supplement (pH 3.5) to an alkaline supplement pH 8.5 (Coppock, Everett and Merrill 1972).

The effectiveness of feedblocks as magnesium carriers for lactating sheep

Several experiments were carried out with lowland ewes during the months of April and May, with ewes either abruptly turned out to spring grass or with previously outwintered ewes. The main criteria of effectiveness were the individual variation in intake, the inter-day variation in total group intake and the plasma magnesium concentrations of the blood of the sheep. The latter parameter is a source of much confusion because of the absence of a meaningful definition of what constitutes a 'normal' plasma magnesium level for sheep. The commonly accepted value for apparently healthy ewes is 2.0 to 2.5 mg/100 ml. Hemingway and Ritchie (1963) measured plasma magnesium levels in 12 different flocks of sheep about 6 weeks after lambing. The mean plasma magnesium varied between 0.99 (Cheviots) and 2.16 mg/100 ml (Half-bred). The overall mean plasma magnesium (389 sheep) was 1.68 mg/100 ml. Many individuals had values < 1.0 mg/100 ml and in 2 cases over half the flock were in this category. The authors stated that only 2 ewes out of the total 389 succumbed to clinical tetany, which was accompanied by severe hypocalcaemia (plasma calcium < 5 mg/100 ml). In several cases lactating ewes in a flock with plasma magnesium values as low as 0.25 to 0.50 mg/100 ml were measured over long periods without any manifestation of clinical tetany. It was concluded that one of the greatest paradoxes encountered in the study of hypomagnesaemia was the high proportion of apparently normal ewes which have plasma magnesium values at or below that level at which clinical tetany may occur in other sheep. There is apparently no minimum level below which clinical tetany is inevitable.

It is also a source of controversy over what exactly is the requirement of lactating sheep for magnesium. The general magnesium recommendation for lactating lowland ewes is 2.6 and 2.2 g/head/day for months 1 and 2 of lactation, respectively (ARC 1965). For the prevention of hypomagnesaemic tetany it is generally assumed that ewes should consume 7 to 14 g of calcined magnesite (4 to 8 g of Mg/head) daily. These levels appear to be only a transposition to sheep of the recommended requirement to prevent tetany in cattle (56 g MgO/head/day). As it appears that frequency of magnesium intake is more important than absolute amount consumed, an advantage of feedblocks, over magnesium given once a day in concentrates cannot be ruled out, despite the many limitations and non-uniformity of feedblock intake already described.

Expt 10.1 The effectiveness of a feedblock containing magnesium oxide as a prophylactic against hypomagnesaemia in lactating ewes transferred from indoor feeding to grazing

The main objective of this initial experiment was to determine if the provision of magnesium oxide in a feedblock would adequately maintain plasma magnesium concentrations of lactating ewes transferred from indoor feeding to grazing. The experiment took place in May, 1975.

Materials and Methods

Twenty four adult Greyface ewes (aged 4 to 6 years) were divided into two groups of 12 such that each consisted of 6 ewes with twin lambs and 6 ewes with single lambs. The ewes had been previously housed and given hay and concentrates during pregnancy and early lactation. Additionally all had been accustomed to consuming feedblocks. The ewes and lambs were abruptly turned out to grass on 7 May when the lambs were about 4 weeks of age.

Two permanent grass (2.5 g Mg/kg) paddocks each of about 0.25 hectares were available. The grass had received 130 kg/hectare ammonium nitrate (340 g N/kg) some weeks previously and the grass growth was good. One group of sheep was offered an experimental-type Colborn feedblock (Colborn-NoMg), containing 9.43 g chromic oxide/kg, but no magnesium oxide inclusion (2.6 g Mg/kg feedblock DM). The other group was given a block (Colborn with Mg) of similar composition but containing added magnesium (49.2 Mg/kg feedblock DM) in the form of magnesium oxide, as well as about 9.43 g chromic oxide/kg. The blocks were weighed daily and replenished when less than the consumption over the previous 24-hour period remained.

Blood samples for the determination of magnesium were obtained immediately prior to turnout and on 8 occasions during the following 21 days. Additionally faecal samples were obtained by grab sampling on days 5 and 7 post-turnout for the determination of chromic oxide, as a means of assessing the individual consumption of block by each individual ewe.

Results

The weather was generally very dry during the experimental period. Over the whole 21-day period the mean consumption of the blocks g DM/ewe/day were 124 $\pm$ 14 (6.1 g Mg) and 106 $\pm$ 14 (0.28 g Mg) for the Colborn with Mg and Colborn-No Mg blocks, respectively. Mean daily intakes of the feedblocks were perhaps greater during days 1 to 4 after turnout and smaller during days 13 to 19. No plasma magnesium concentrates less than 1.0 mg/100 ml were measured for individual ewes, irrespective of type of supplementation.

The mean concentrations ($\pm$ SE) of magnesium in the blood and chromic oxide in the faeces of the ewes are given in Table 32. There was a pronounced and highly significant ($P < 0.001$) decline in plasma magnesium concentrations for both groups of ewes during the first 7 days of grazing. Further reductions occurred after 12 to 14 days but thereafter there were small increases for both groups. On each occasion when blood samples were obtained the ewes receiving the Mg supplement had higher concentrations of magnesium in the blood. The difference was significant ($P < 0.05$) on days 9 and 12 and almost significant on days 2, 5 and 7.

Table 32 Expt 10.1 Mean (± SE) plasma magnesium and faecal chromic oxide concentrations for ewes given Colborn-type feedblocks with or without magnesium

	Mean plasma Mg mg/100 ml			Faecal chromic oxide g/100 kg DM	
	Colborn with Mg	Colborn No Mg	Level of Significance	Colborn with Mg	Colborn No Mg
Pre-turnout	2.77±0.13	2.69±0.10	NS	-	-
Post-turnout (days)					
2	2.09±0.13	1.77±0.10	NS	-	-
5	1.60±0.09	1.35±0.08	NS	186 (58.1)+	148 (58.8)
7	1.57±0.08	1.37±0.07	NS	152 (76.1)	90 (64.1)
9	1.72±0.08	1.41±0.04	P 0.05	-	-
12	1.88±0.07	1.63±0.07	P 0.05	-	-
14	1.54±0.07	1.50±0.09	NS	-	-
19	1.67±0.08	1.58±0.08	NS	-	-
21	1.81±0.08	1.67±0.06	NS	-	-

+CV %

Only one grab sample had a faecal chromic oxide below 10 g/100 kg faecal DM (2.8 g chromic oxide/100 kg for the Colborn with Mg block at the sampling 7 days post-turnout), suggesting that this ewe was not consuming feedblock in any quantity (the faecal chromic oxide concentration at 5 days post-turnout was 14 g/100 kg DM). The mean coefficients of variation for days 7 and 9 were 67.1 and 61.5%, for the with Mg and No Mg ewes, respectively, indicating that there was only slightly more individual variation in intake between individuals when magnesium oxide was included in the block.

There were no significant correlations (irrespective of whether Colborn blocks with or without magnesium were given) between the individual plasma magnesium concentrates at 2 or 5 days post-turnout, or when meaned together and faecal chromic oxide concentrations at 5 or 7 days post-turnout, or when both faecal samples were meaned together. Neither was the percentage decrease in plasma magnesium (the 2 and 5 day post-turnout samplings combined and compared with the pre-turnout values) significantly correlated ($r = -0.48$) with the concentration of chromic oxide in the faeces of individual sheep.

The ewes suckling twin lambs did not have significantly lower plasma magnesium concentrations or vastly different faecal chromic concentrations than ewes suckling single lambs.

Discussion

The absence of any significant relationship between plasma magnesium and faecal chromic oxide concentrations for individual sheep, when given feedblocks containing MgO was probably due to the small number of sheep per group. However only one (Colborn with Mg block) of the total 24 ewes appeared not to be consuming significant quantities of either feedblock. This interest in the block was maintained despite the presence of abundant high quality spring grass which was shown in Section 2 to be preferred exclusively by lactating beef cattle given Rumevite-type feedblocks.

It was concluded in Expt 10.1 that the provision of a Colborn-type feedblock supplying a mean additional 6.1 g Mg/ewe/day had a small but significant effect on increasing the concentration of magnesium in the blood plasma of ewes. The experimental results were not such as to indicate whether this level of intake might have been effective under conditions where clinical hypomagnesaemic tetany could have occurred.

Expt 10.2 A comparative assessment of the effectiveness of a feedblock and a 'Free-Access' mineral mixture both containing magnesium oxide as prophylactics against hypomagnesaemia in lactating ewes at grass

This experiment differed from Expt 10.1 in that the sheep used had been outside all winter, during which time they had continuously received feedblocks until lambing. Also two different 'self-help' methods of giving supplementary magnesium were compared, feedblocks and 'free-access,' minerals. The experiment was carried out in May 1975.

Materials and Methods

Two groups each of 14 Greyface ewes (2 to 6 years old) with lambs (7 ewes with twins and 7 ewes with single lambs) aged about 2 to 4 weeks, were transferred to two separate and comparable paddocks (0.5 hectare) of permanent grass. The paddocks had previously received 130 kg ammonium nitrate/hectare.

One group were given a feedblock (Colborn with Mg) of similar composition to that used in Expt 10.1 (49.2 g Mg and 9.43 g chromic oxide/kg DM). The block was weighed daily and replaced when less than the previous 24-hour consumption remained. The other group were given ad libitum access to a proprietary mineral supplement (Tuco Ltd.), containing 172 g Mg/kg present as magnesium oxide, to which was added chromic oxide to give a concentration of 14.45 g Cr_2O_3/kg mineral mixture. The mineral mixture was also weighed daily by recording the gross weight of mineral supplement plus container and deducting the weight of the container to give the net amount consumed.

Blood samples were obtained from each ewe immediately before the start of the trial on 15 May and on 4 occasions during the next 10 days. Faecal grab samples were obtained on day 5 (20 May).

Results

There was very little rainfall during the trial and the weather was generally warm. The mean daily intakes of the feedblock and mineral supplement were 77 $\pm$ 13 g (3.8 $\pm$ 0.6 g Mg) and 37 $\pm$ 13 (6.4 $\pm$ 2.2 g Mg) g DM/head. These values assume that none of the materials were consumed by the lambs. The consumption of the mineral supplement was negligible on 4 of the 10 days of the experiment. The consumption of the (Colborn with Mg) block was negligible on one day only.

Both supplements significantly increased the initially very low (only 4 ewes with values $>$ 1.0 mg/100 ml and 2 ewes less than 0.5 mg/100 ml) mean plasma magnesium concentration of about 0.8 mg/100 ml to about 1.1 to 1.3 mg/100 ml, within 1 to 3 days (Table 33), but there were no significant differences between treatments. In each case values were increased most for the ewes with lowest initial concentrations.

The mean concentrations of chromic oxide in the DM of the faecal grab samples obtained on day 5, were, 73 $\pm$ 13 and 43 $\pm$ 10 g/100 kg faecal DM, the coefficients of variation being 65.1 and 79.7% for the feedblock and mineral supplement, respectively. This indicates that the individual intake of magnesium was perhaps rather more variable for those ewes given the mineral supplement. One ewe in the feedblock group and 2 ewes in the mineral supplement group had faecal chromic oxide concentrations below or only just greater than 10 g/100 kg faecal DM.

There were no significant correlations between individual faecal chromic oxide concentrations (day 5) and plasma magnesiums (days 1 and 3 meaned) or percentage increase in plasma magnesium (the increase in plasma by day 5, expressed as a percentage of the pre supplementation level) concentration.

Discussion

The pre supplementation plasma magnesium concentrations for the ewes in Expt 10.2 were very low (individual values down to 0.25 mg/100 ml), yet still no clinical symptoms of hypomagnesaemic tetany occurred.

Table 33 Expt 10.2 Mean (± SE) plasma magnesium concentrations mg/100 ml

	Colborn + Mg	'Free-Access' mineral supplement
Pre supplementation	0.80 ± 0.06**	0.76 ± 0.07*
Post supplementation		
Day 1	1.11 ± 0.06	1.06 ± 0.09*
3	1.26 ± 0.08	1.32 ± 0.06
5	1.18 ± 0.07	1.16 ± 0.05
10	1.07 ± 0.05	1.30 ± 0.08

This phenomenon is in agreement with the findings of Hemingway and Ritchie (1963), who reported plasma magnesium concentration of lactating ewes of 0.25 to 0.50 mg/100 ml for long periods without any evidence of clinical tetany.

Both supplements appeared to be reasonably effective in increasing the plasma magnesium concentrations of the sheep. All individuals in both groups showed a response to the supplements in terms of increased plasma magnesiums which was largely maintained over the experimental period. It is possible but rather unlikely that plasma magnesium concentrations may have increased partly as a result of the pasture change, independently of the provision of supplementary magnesium.

The 'free-access' mineral supplement supplied a higher mean daily intake of magnesium (6.4 g) than the (Colborn with Mg) feedblock (3.8 g). Although the former suffered from several days when group intake was apparently negligible, whilst only on one day was the feedblock intake considered to be unmeasurable by weighing. There was also slightly more individual variation in intake for the mineral supplement.

Expt 10.3 Individual variation in magnesium intake for ewes given either feedblock or concentrates offering a similar total amount of magnesium per day

In Expts 10.1 and 10.2 individual feedblock intakes were based on the use of rectal grab samples which are less accurate than intakes based on total faecal collections. Therefore in Expt 10.3 total collections of faeces were attempted. Also, in the two previous experiments, individual variation in feedblock intake, although considerable, could not be related to individual variation arising from other techniques of magnesium supplementation (apart from 'free-access' minerals in Expt 10.2). In Expt 10.3 a concentrate control treatment was included where total amount allocated was fixed daily, with the intention of supplying about 12 g of magnesium oxide/head.

On one day during Expt 10.3 both the feedblock and concentrate sheep were bled on three occasions to examine the effect of pattern of magnesium intake (little and often for blocks) on plasma magnesium values.

Materials and Methods

Thirty four Greyface (Border Leicester ♂ x Scottish Blackface ♀) ewes were divided into 2 groups (M and N) of 17 animals. The number of ewes non-lactating, suckling single or twin lambs were 9, 4, 4 and 8, 5, 4 for groups M and N, respectively. The majority of the ewes had lambed indoors between 4 and 12 April, 1976 and had received hay plus both feedblocks and concentrates for a 4-week period prior to transfer to two adjacent paddocks each of about 0.25 ha on 14 May. The paddocks had received a liberal application of nitrogenous fertiliser about 25 days previously and provided generous 'lush' spring grass.

Group M ewes were given an experimental Colborn feedblock containing 44.5 g Mg/kg DM, no container was used and the block was weighed daily at 09.00 hr. Group N ewes received daily, 210 g DM/head of a barley-concentrate pellet containing 48.9 g Mg/kg DM (10.3 g magnesium/day). This was given (09.00 hr) in troughs with a space allowance of 200 cm/head. The magnesium source in both feedblock and concentrate was Spanish magnesium oxide. The feedblock and concentrate contained chromic oxide (9.88 and 8.28 g/kg DM, respectively). The ewes were equipped for total quantitative faecal collection using harnesses and nylon mesh faecal bags. Faeces were collected from both groups over a 4-day (days 12 to 15 post-turnout) period and were sampled according to Method 2 in the Introduction. Individual concentrate or feedblock intakes were calculated according to the amount of chromic oxide recovered.

Blood samples were taken by jugular venapuncture (08.00 hr) from the ewes 1 day before turnout and 3, 10 and 15 days post-turnout. On the latter occasion the ewes were bled 3 times at 08.00, 12.00 and 16.00 hrs. All samples were analysed for plasma magnesium concentration.

Results

There were no clinical cases of hypomagnesaemic tetany. The weather conditions during the experiment were generally dry. The mean daily DM intake (obtained by daily weighing) of the experimental Colborn feedblock was 180 $\pm$ 20 g/head over the whole experiment. Individual magnesium intakes from either feedblock or concentrate are presented in Table 34. The mean daily DM intakes of feedblock and concentrate (obtained by calculation of chromic oxide in faeces) were 157 and 173 g/head for groups M and N, respectively. The CV for feedblock intake (55.6%) was almost twice the concentrate value (29.8%). The mean intakes of ewes suckling twin lambs (160 g/head) and given feedblock (group M) was 51% greater than the intake (106 g/head) of the non-lactating ewes, but 21% less than the intake (202 g/head) of ewes suckling single lambs.

The mean intakes (192 g/head) of ewes suckling twin lambs and given concentrates (group M) was 19 and 30% greater than the mean intakes (162 and 148 g/head) of single suckling and non-lactating ewes, respectively.

One ewe in each group consumed more than 12 g Mg/head/day from the supplements. The lowest individual Mg consumption (3.4 g/head) for the sheep given the concentrate supplement was by a ewe suckling a single lamb. Only 2 sheep consumed appreciably less than 6 g/head. Five of the total of 17 ewes given the feedblock had daily magnesium intakes well below 6 g/head (including 3 of 9 ewes suckling twin lambs).

Table 34 Expt 10.3 Individual feedblock and (magnesium) intakes (g)

	Colborn-type feedblock			Concentrates	
Non-lactating	Singles	Twins	Non-lactating	Singles	Twins
29 (1.3)	147 (6.5)	37 (1.6)	92 (4.5)	118 (3.4)	128 (6.3)
34 (1.5)	207 (9.2)	52 (2.3)	121 (5.9)	138 (6.7)	138 (6.7)
129 (5.7)	226 (10.0)	88 (10.0)	137 (6.7)	163 (8.0)	177 (8.7)
232 (10.3)	229 (10.2)	133 (5.9)	242 (11.8)	165 (8.1)	191 (9.3)
		152 (6.7)		226 (11.0)	197 (9.6)
Mean					
106 (4.7)	202 (9.0)	179 (7.9)	148 (7.2)		197 (9.6)
		233 (9.9)		162 (7.4)	217 (10.6)
		254 (11.3)			288 (14.1)
		319 (14.2)			
					192 (9.4)
		160 (7.1)			
Over all Mean feedblock or magnesium intake	157 (7.0)			173 (8.3)	
CV	55.6%			29.8%	

Table 35 Expt 10.3 Mean (± SE) plasma magnesium concentrations (mg/100 ml) for sheep given either feedblocks or concentrates containing magnesium

		Feedblock		Concentrate
Pre-turnout				
Non-lactating	4)[+]	2.71±0.07	4)	2.76±0.03
Singles	4)	2.71±0.07	5)	2.86±0.03
Twins	9)	2.80±0.04	8)	2.81±0.08
1 day post-turnout				
Non-lactating		2.30±0.19		2.30±0.08
Singles		2.15±0.06		2.29±0.09
Twins		2.34±1.00		2.42±0.14
10 days post-turnout				
Non-lactating		2.32±0.24		2.26±0.04
Singles		2.24±0.13		2.35±0.12
Twins		2.09±0.09		2.26±0.10

	Feedblock Time (hr) 08.00	12.00	16.00	Concentrate Time (hr) 08.00	12.00	16.00
15 days post-turnout						
Non-lactating	2.39±0.23	2.71±0.05	2.48±0.23	2.35±0.10	2.59±0.02	2.49±0.09
Singles	2.42±0.23	2.47±0.20	2.54±0.20	2.58±0.09	2.77±0.12	2.72±0.07
Twins	2.33±0.18	2.38±0.10	2.41±0.10	2.34±0.07	2.60±0.05*	2.62±0.06*
All ewes	2.36±0.09	2.48±0.07	2.46±0.08	2.42±0.06	2.65±0.05**	2.63±0.04**

[+] number of ewes in category.

The plasma magnesium concentrations at the various samplings for the ewes are given in Table 35. The mean plasma magnesium concentrations 1-day post-turnout had decreased significantly ($P < 0.001$) from the pre-turnout levels of 2.71 and 2.76 mg/100 ml to 2.28 and 2.35 mg/100 ml, for the feedblock and concentrate groups, respectively. At the 10-day post-turnout sampling, mean plasma magnesium for both groups had further decreased slightly, but not significantly to 2.18 and 2.29 mg/100 ml, respectively. Fifteen days post-turnout the mean plasma magnesium concentrations had increased again for both groups of ewes (2.36 and 2.42 mg/100 ml). This increase was not significant. There were no significant differences in mean plasma magnesium concentrations at 08.00 hrs for both feedblock and concentrate supplemented sheep, irrespective of number of lambs being suckled.

The mean plasma magnesium of the concentrate supplemented ewes (2.65 and 2.63 mg 100 ml at 12.00 and 16.00 hr, respectively) were significantly ($P < 0.01$) higher than the concentration at 08.00 hrs (2.42 mg/100 ml). There were no significant differences in plasma magnesium concentrations for the feedblock supplemented ewes when the 3 samples were taken on one day. There were no significant correlations between calculated magnesium intakes and plasma magnesium concentrations for either group of ewes at any of the sampling periods.

Discussion

The consistency of the faeces during the experiment was very soft making quantitative collection of the faeces difficult, which probably accounts for the discrepancy (underestimate) between calculated magnesium intakes and total amount of magnesium allocated. The mean calculated feedblock and concentrate intakes were only about 86 and 82%, respectively, of the mean quantities allocated. Therefore it is likely that some faeces were lost and that the feedblock (magnesium) intakes quoted are less accurate than in other experiments, when total collections have been used to estimate individual supplement intakes. They are nevertheless still far more reliable estimations of individual intakes than those based on rectal grab samples.

The higher CV for individual feedblock than concentrate intake is in agreement with the results of Section 1, where in virtually all circumstances, concentrates were a more precise means of giving nutrients than feedblocks. All ewes consumed some feedblock but the intakes were low for 5 of the 17 sheep.

There was no evidence to suggest that ewes suckling twin lambs and given feedblock would consume greater quantities of magnesium than ewes suckling single lambs. Both categories however consumed appreciably more feedblock (magnesium) than non-lactating ewes.

Although the small numbers of sheep in each category limited the confidence which could be placed on the results, several of the ewes suckling twins had supplementary magnesium intakes below 4 g/head, whilst no ewes suckling twins and given concentrates had daily magnesium intakes below 6 g/head. In fact, the mean magnesium intakes from concentrates were even ranked according to likely requirements, with non-lactating ewes consuming less than ewes suckling either single or twin lambs. Ewes suckling one lamb consumed less than ewes suckling twin lambs.

Although plasma magnesium concentrations decreased significantly upon turnout there were no clinical cases of hypomagnesaemic tetany. The lowest plasma magnesium concentrations measured were about 1.7 mg/100 ml which is hardly indicative of a subclinical hypomagnesaemic condition. (The mean magnesium concentrations measured by Hemingway and Ritchie (1963) for 389 lactating sheep was 1.68 mg/100 ml). In the absence of a group of sheep given no supplementary magnesium it was difficult to assess whether the absence of low plasma magnesium concentrations reflected the success of the supplements used or not. There were however no correlations between supplement intakes and plasma magnesium concentrations. Therefore it is possible that the sheep used in this experiment were in a non-critical situation where supplementary magnesium was not required.

By the time the sheep were turned out, most had been lactating for 4 to 6 weeks and the demand for magnesium may have lessened as milk production decreased. Therefore the sheep had perhaps been turned out too late in lactation to be in a truly sensitive situation, where hypomagnesaemic tetany was likely to occur. Most of the ewes were also relatively young (second crop of lambs) and were consequently less predisposed to tetany (Hemingway, Inglis and Ritchie, 1960).

When the sheep given feedblock were bled on 3 occasions during a 24-hr period, there was little difference in mean plasma magnesium concentration. The sheep given concentrates had significantly elevated levels 3 and 7 hours after giving the daily allocation, than 1 hour before. This emphasises the importance of time of bleeding in relation to when magnesium is given, particularly if given in a single daily allocation.

The results of this experiment agreed with those of Expt 10.1, in that there was no evidence to suggest a relationship between magnesium intake from 'self-help' feedblocks and number of lambs suckled for lactating sheep. However, both the feedblock and concentrate supplements were effective in the experimental circumstances because all sheep consumed at least some supplementary magnesium and no cases of clinical tetany occurred. It is virtually impossible to evaluate accurately different methods of giving supplementary magnesium to sheep unless clinical cases of tetany are produced, because of the uncertain nature of plasma magnesium concentrations and the absence of any well defined criteria scientifically established requirement for magnesium by lactating sheep.

Furthermore because of the complex nature of acute ruminant hypomagnesaemia, indicating it to be a matabolic rather than a nutritional disease it is perhaps an oversimplification to expect any relationship between intake and need to exist.

Expt 10.4 The acceptibility and individual variation in intake of experimental feedblocks containing magnesium

In Expts 10.1, 10.2 and 10.3 lactating sheep consumed small quantities of magnesium-containing Colborn-type experimental feedblocks at spring grass. The object of Expt 10.4 was to further assess the acceptibility and individual variation in intake of this and other feedblock types, with groups of ewes previously outwintered, or ewes abruptly turned out to spring grass after being housed during the winter. The effect of change in herbage availability on feedblock intake was also studied by giving the sheep a 'fresh-bite' of spring grass, after previously grazing a bare pasture.

Material and Methods

The experiments were all carried out in April and May 1976 on the University of Glasgow Field Station, Cochno Farm. Apart from one trial when Dorset Horn ewes were used all the sheep employed were Greyfaces (Border Leicester ♂ x Scottish Blackface ♀).

The feedblocks used were essentially similar or the same in terms of composition and manufacturing process to those described in the Introduction (Table 1) except that the inclusion rate and/or source of magnesium was changed. The following trials were carried out.

Trial I.

Twelve Dorset Horn ewes with 15 lambs were turned out on the 29 April into a 0.5 ha paddock with ample spring grass (permanent pasture) after previously being housed during the winter. The ewes had lambed about 3 to 4 weeks before and received feedblocks inside. Three slightly different blocks were given simultaneously to the sheep; (a) a Colborn-type block containing MgO (as used in Expt 10.1); (b) a Colborn-type block containing magnesium phosphate (MgP, 200 g Mg, 185 g P/kg) giving 28.1 g Mg/kg and 23.6 g P/kg feedblock DM and (c) a Colborn-type block containing no added magnesium. The blocks were weighed daily.

The ewes were bled (for magnesium) 3, 10, 16 and 25 days post-turnout and rectally grab sampled 10 days post-turnout. (All three feedblocks contained about 9.5 to 1.0 g chromic oxide/kg block DM).

Trial II

Ten Greyface ewes with twins and 5 non-lactating ewes were turned out (29 April) into a 1 ha paddock of liberally fertilised permanent pasture. The ewes had previously been housed during the winter and had been lactating for 3 to 4 weeks. Two experimental Rumevite feedblocks were given to the ewes containing either MgO or MgP as the magnesium source (18 and 50 g Mg/kg feedblocks DM respectively). The blocks were weighed daily. The sheep were bled 1 day before turnout (28 April) and 1 and 7 days post-turnout.

Trial III

Thirty Greyface ewes and 45 lambs had been given access to a field (8 ha) of permanent pasture for several weeks, during which time they had lambed. Initially the pasture was very bare but gradually spring grass became available to the ewes. During this time the sheep had been given 2 experimental Colborn blocks containing MgO, similar in composition to those used in Expt 10.3 (44.5 g Mg 9.5 g chromic oxide/kg block DM). The intakes of the blocks were monitored by daily weighing. On 5 and 10 May the sheep were bled and rectally grab sampled.

Trial IV

Fifty one Greyface ewes with 80 lambs had been grazing a relatively bare pasture for about 3 weeks. The ewes lambed 3 to 5 weeks earlier. On 8 May the sheep were moved to a 'fresh-bite,' of 'lush' spring grass in a paddock of about 4.5 ha. During the previous weeks and throughout the movement period the sheep had been given two W290(76) feedblocks (12 g Mg/kg feedblock DM), the intakes of which were monitored by daily weighing.

The sheep were bled 3 days before, and 2 and 6 days after changing pastures, (on the 5, 10 and 14 May, respectively). Rectal grab samples were obtained 3 days before and 6 and 12 days after changing pasture.

Trial V

Thirty five Greyface ewes with 60 lambs had received Rumevite-type feedblocks (RS or RHE) outdoors for several months previously. The ewes lambed during March and were grazing a very bare pasture and consuming appreciable amounts of RHE feedblocks (92 g/head). On 8 May the ewes were moved to a 4 ha paddock which contained ample 'spring grass,' (previously, heavily fertilised with nitrogen). In addition the ewes were given a RHE and Rumevite 'Springblok' (a proprietory high magnesium (60 g Mg/kg Block DM) feedblock, purposefully designed for use during times when hypomagnesaemia is likely to occur). On 5 and 10 May the ewes were bled (3 days pre- and 2 days post-changing pastures respectively).

Results

In Trial I the daily intakes of the MgO, MgP or No-Mg Colborn-type blocks were 39 $\pm$ 8, 28 $\pm$ 7 and 49 $\pm$ 12 g DM/head (a mean 2.5 g Mg/head in total). These differences in intakes were not significant. The mean plasma magnesium concentration 3 days post-turnout (2.31 $\pm$ 0.01 mg/100 ml) was significantly ($P < 0.001$) lower than the pre-turnout mean concentration (2.71 $\pm$ 0.02 mg/100 ml). There were no significant differences in plasma magnesium concentrations 10, 16 and 25 days post-turnout (2.37, 2.41 and 2.51 mg/100 ml, respectively), although levels progressively increased. The CV for faecal chromic oxide concentration was 79.1% with a range in concentration of 14 to 230 g/100 kg faecal DM (Mean = 83 g/100 kg faecal DM).

In Trial II with Rumevite-type blocks the sheep completely refused to consume any feedblock and the experiment was discontinued 7 days after turnout. The mean plasma magnesium decreased significantly ($P < 0.001$) from a pre-turnout level of 2.91 $\pm$ 0.07 mg/100 ml to

2.39 ± 0.05 mg/100 ml 7 days post-turnout.

The mean daily intake of the MgO-containing Colborn block during Trial III was 118 ± 7 g DM/head (5.3 ± 0.3 g Mg/head). There was a slight but non significant decrease in mean plasma magnesium concentration from 2.10 to 1.95 mg/100 ml between the 2 samplings. The range in plasma magnesium concentrations was 1.43 to 2.69 mg/100 ml. On the 5 May, of the 17 ewes, from which faeces samples were obtained, three did not appear to be consuming feedblock. The CV for faecal chromic oxide for the remaining 14 ewes was 82.7%, range 21 to 535 g chromic oxide/100 kg faecal DM (mean = 128). At the second sample (10 May), 22 ewes were grab sampled, including 2 individuals which did not appear to be consuming block. The CV was now 72.9%, range 16 to 673 g chromic oxide/100 kg faecal DM (mean 241).

In Trial IV the mean daily intake of W290(76) on the bare pasture was 59 ± 8 g DM/head (0.71 ± 0.10 g Mg). When the ewes were transferred to 'lush' spring grazing the mean daily intake of W290(76) increased surprisingly to 84 ± 10 g/head (1.0 ± 0.01 g Mg). The difference was not significant. The mean plasma magnesium concentration on the bare pasture (1.96 ± 0.05 mg/100 ml, range 0.99 to 2.63) was significantly ($P < 0.01$) higher than 2 days after the ewes were moved to 'lush' spring grass (1.76 ± 0.04 mg/100 ml, range 1.18 to 2.28). When the ewes were sampled 6 days after the move, the mean plasma magnesium concentrations (1.96 ± 0.05 mg/100 ml; range 1.43 to 1.69) had significantly increased again.

Before moving the ewes, rectal grab samples were obtained from 28 individuals of which 5 were considered not to be consuming any block (faecal chromic oxide < 5 g/100 kg DM). The CV for the remaining 23 ewes was 75% with faecal chromic oxide ranging from 7 to 61 g/100 kg DM (Mean = 19). When the ewes were grab sampled 6 days after moving, only 1 of the 37 samples obtained had a faecal chromic oxide concentration of below 5 g/100 kg DM. The CV for feedblock intake for the remaining ewes was 82.9% with a range of values 7 to 139 g/100 kg DM (Mean = 44). Twelve days after changing pasture 43 grab samples were obtained, of which 6 had very low levels of chromic oxide and these ewes were assumed not to be consuming block. The CV for the remaining 37 ewes was 90.0% with a range of faecal chromic oxide concentrations of 9 to 244 g/100 kg DM (Mean = 60). There were no significant correlations between plasma magnesium and faecal chromic oxide concentrations.

After being moved to a fresh pasture containing ample spring grass, the ewes given Rumevite-type blocks in Trial V failed to consume any feedblock whatsoever. The mean plasma magnesium concentration remained constant (1.77 and 1.79 mg/100 ml), when the sheep were bled before and after moving. One ewe had a very low concentration of 0.58 mg/100 ml at the pre-change bleeding which surprisingly increased to 1.23 mg/100 ml after changing pasture.

Discussion

As in Expts 10.1, 10.2 and 10.3 no clinical cases of hypomagnesaemic tetany occurred in any of the ewes, irrespective of whether housed during the winter and abruptly changed to pasture, or outwintered. In fact, in only one instance was a plasma magnesium concentration of appreciably less than 1.0 mg/100 ml measured. The lowest mean plasma magnesium concentration for a group of ewes (1.77 mg/100 ml), occurred in Trial V, which even then exceeded the mean value (389 ewes) of 1.68 mg/100 ml measured by Hemingway and Ritchie (1963). Therefore there was not even the slightest indication in any of the trials of real critical need for supplementary magnesium, which is substantiated by the absence of any clinical case of hypomagnesaemic tetany in the sheep for the experiment described here.

As mentioned in Expt 10.3, against an experimental background where no clinical tetany occurs, it is rather difficult to meaningfully evaluate magnesium-containing supplements for sheep. Also in the trials described here, no alternative means of administering supplementary magnesium were included and a comparative assessment of feedblocks could not be made. However, it can be reasonably assumed that a complete failure to consume a supplement is indicative of a gross inadequacy of its effectiveness under the experimental circumstances. Alternatively, those supplements consumed at a reasonable level and showing the lowest individual variation in intake are likely to be most suitable for the majority of situations. Therefore some indication of feedblock (magnesium) supplement effectiveness can be assessed from the trials described here.

In Trials II and V the complete failure of the sheep to consume Rumevite-type feedblocks, either of an experimental or normal production nature severely militates against their use at critical times when hypomagnesaemic tetany is likely to occur.

In Trial I, when 3 Colborn-type feedblocks differing only in magnesium inclusion and magnesium source were simultaneously given to Dorset Horn ewes, there was a slight but not significant preference for the block containing no magnesium fortification. The mean daily intake from magnesium from all 3 blocks (2.5 g Mg/day) was greater than Trial IV when the sheep received W290(76) (0.7 g MG/head), but considerably less than Trial III (5.3 g Mg/head) when Colborn blocks containing MgO only, as a magnesium source were given. In Trials III and IV a varying proportion (10 to 20%) of the ewes sampled were not consuming block. In Trial I the low number of sheep (12) may have been somewhat inadequate and it is likely that if a larger group were used, a proportion would also refuse to consume block. Of the ewes apparently consuming block there was very considerable variation in individual intake, characterised by a many fold (16 to 40) difference in faecal chromic oxide concentration.

There were also considerable inter-day fluctuations in total group intake of feedblock (magnesium) which in a critical situation could only have been detrimental to the sheep.

Of the five trials reported here, the most effective situation in terms of proportion of sheep consuming the feedblock and mean magnesium intake occurred during Trial III, when the ewes had continuously received a Colborn-type feedblock containing MgO for several weeks. Feedblock/magnesium intake was maintained at a relatively high mean level (5.3 g Mg/head) as the grass gradually became available to the sheep. Even in this situation some ewes were apparently not consuming the block.

The W290(76) feedblock used in Trial IV had a low magnesium content (12 g Mg/kg Block DM), but was consumed at a relatively high level both before and after offering better quality grazing. Also the proportion refusing to consume the block 6 days after changeover (3%) was low.

The results of these trials and the previous experiments with sheep using feedblocks as magnesium carriers during the critical spring period re-emphasise clearly the imprecise nature (Section 1) of feedblock supplementation relative to trough given nutrients. When 'self-help' systems are employed to provide magnesium to help prevent hypomagnesaemia, they suffer from another important disadvantage, apart from those previously described. The stockfeeder has no means of identifying practically those individuals not consuming the supplement, while with supplementary magnesium given in concentrates in troughs, 'shy-feeders' can be easily identified and given special management. This may take the form of intensive observations during the critical periods and/or alternative precautions may be taken such as the administration of magnesium-containing rumen bullets.

Even under the most favourable conditions it is difficult to visualise a situation where supplement-type feedblocks can be even partly successful as magnesium carriers for sheep, during the critical spring period, if abundant high quality grass is available. The more palatable substitute-type feedblocks may be useful sources of magnesium to sheep in some situations, but their reliability must be open to question until evaluated extensively in sensitive situations, where clinical hypomagnesaemic tetany is occurring.

The use of magnesium-containing feedblocks for the control of hypomagnesaemia in cattle

The previously described experiments where the evaluation of feedblocks as magnesium carriers to combat hypomagnesaemic tetany in sheep was attempted, emphasised some significant limitations which may equally apply to cattle. The difficulties of sensibly designing experiments where hypomagnesaemia is studied were also very apparent. The situation however is somewhat simplified in cattle, because of a more precise definition of what constitutes a hypomagnesaemic state, in terms of plasma magnesium concentration. It is generally considered that the normal range for cattle is from 2.0 to 3.5 mg Mg/100 ml.

There is still nevertheless a great deal of controversy, concerning the recommended quantity of magnesium required to prevent clinical tetany. The recommended prophylactic dose for cattle is 56 g (2 ozs) of calcined magnesite/day (about 30 g Mg, as MgO is generally 87% pure). The magnesium requirement for lactating cows (ARC 1965) giving 10 kg of milk/day is about 19 g Mg/day, assuming an availability of the magnesium in the diet of 20%. As with sheep it is likely that in the prevention of hypomagnesaemic tetany the pattern of magnesium intake is more important than absolute amount given. A small quantity of magnesium ingested frequently, as is possible with 'self-help' systems may be better than a larger quantity ingested only once/day.

Two experiments were carried out in successive years with lactating suckler cows, with the intention of evaluating different feedblock types as magnesium carriers, during the critical spring post-turnout period. A comparative assessment of feedblock effectiveness was carried out in one year by giving half the cows magnesium in concentrates form, offered in troughs.

Expt 11.1 The effectiveness of Rumevite-type feedblocks containing either magnesium oxide or magnesium phosphate as a prophylactic against hypomagnesaemia, in suckler cows transferred abruptly to grazing

In many instances feedblocks are employed specifically as magnesium carriers to aid in the prevention of hypomagnesaemia in cattle. One such situation where they may be used is during the critical post-turnout period in the spring, when lactating dairy or beef cows undergo a fundamental change in diet from that given over the winter.

It was the intention of the present and the succeeding experiment to assess the effectiveness of feedblocks containing magnesium in this role.

Materials and Methods

The experiment took place in May/June 1975. Twenty four beef-type suckler cows, with calves aged 6 to 8 weeks, had received a diet consisting of 3 kg barley + urea/head with ad libitum oat straw, over the winter period. About 2 weeks after calving the cows were additionally given RHE feedblocks (49.2 g Mg/kg DM), the consumption of which increased rapidly over about a week to a mean intake of about 500 g DM/head/day. The oat straw was then reduced and the cows given ad libitum silage plus feedblocks (RHE) and concentrates until the cows were transferred to grass. The voluntary intake of block over this period was maintained at about 400 to 500 g DM/head/day.

Two adjacent fields of permanent pasture (A, 4.0 ha and B, 2.8 ha) with a central holding pen were used for the experiment. Each had been given 90 kg/ha nitrogen as ammonium nitrate and the herbage was growing rapidly. In a previous year (1973) 3 clinical cases of hypomagnesaemic tetany had occurred in a group of 15, of virtually the same cows in these fields and the giving of 53 g magnesium phosphate (MgP)/day in 1 kg barley to another group of cows had maintained plasma magnesium concentration.

In the present experiment the cows were divided into 2 groups of 12 and were turned out to fields on 20 May. One group of cows was given an experimental Rumevite-type feedblock (50.5 g Mg, 9.6 g P, 172 g NaCl and 7.83 g chromic oxide/kg DM) containing magnesium phosphate (200 g Mg and 185 g P/kg) (R-MgP). The second group of cows was given RS feedblock of similar composition to Table 1 (17.8 g Mg, 169 g NaCl, 3.23 g chromic oxide/kg DM). Initially the blocks were placed in the purpose-built Rumevite containers. The blocks were weighed daily.

The cow groups were alternated from field to field every 2 or 3 days to minimise the differences in enclosure size and herbage between the two fields.

The cows were bled (for plasma magnesium determination) prior to and 2, 31, 46, 50 and 56 days post-turnout. Rectal grab samples (for chromic oxide determination) were obtained 31, 46, 50 and 56 days post-turnout.

Results

The weather was very dry throughout the citical turnout period. (There was no measurable rainfall after turnout until 1 June) and during the experimental period in general. No clinical cases of hypomagnesaemic tetany occurred.

Both groups of suckler cows refused to consume their respective supplements in measurable quantities throughout the critical 3-week period immediately post-turnout. Several means were tried in an attempt to interest the cows in the blocks. These included moving the blocks close to the water troughs, removing them from the containers and splashing water over them. However it was not until most of the flush of grass had been consumed that the cows started to consume the blocks.

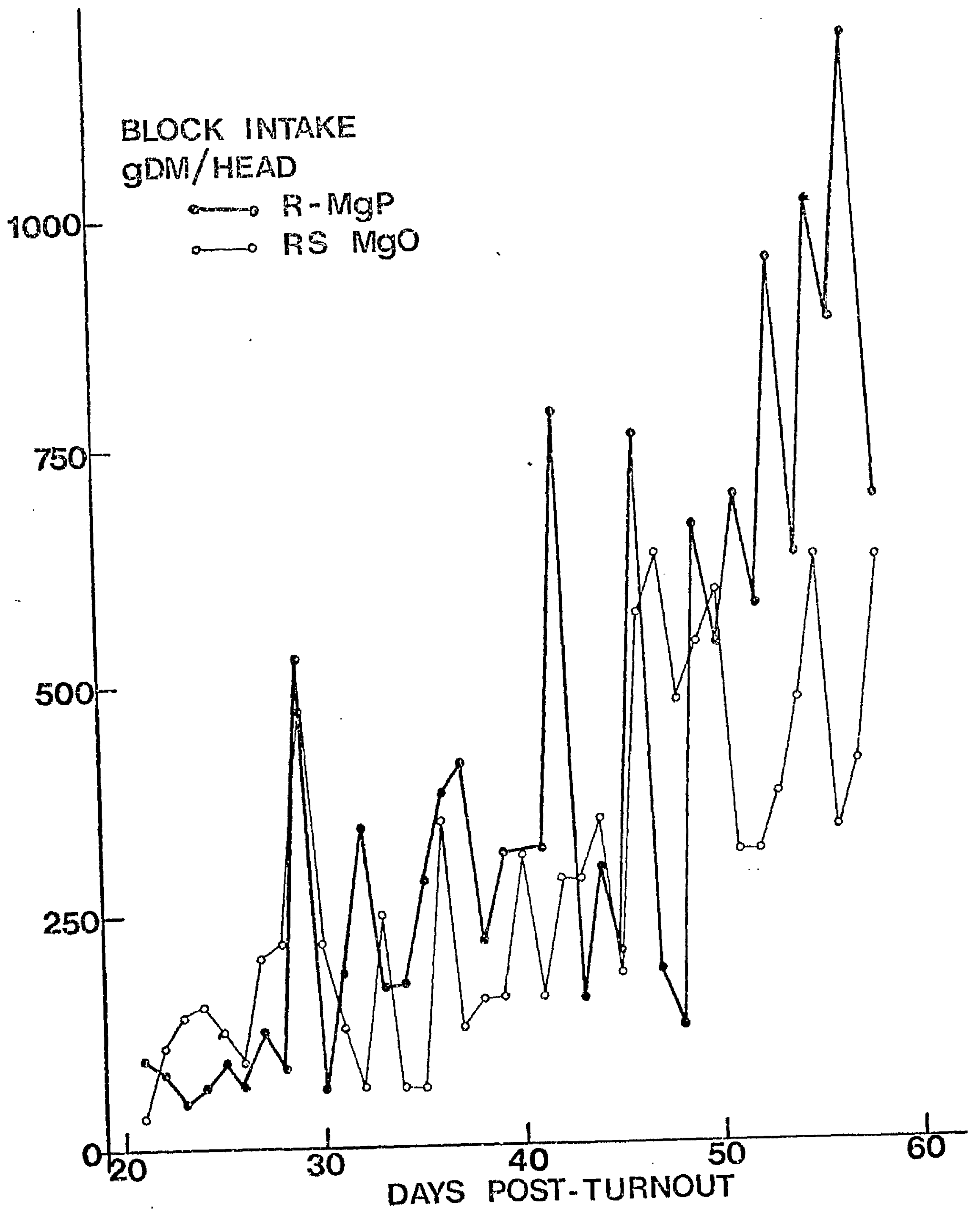
The mean daily intakes of the R-MgP and RS feedblocks from about 10 June to 17 July (38 days) were 388 ± 50 (20 g Mg) and 285 ± 30 (5.1 g Mg) g DM/head, respectively. The difference in mean intakes was not significant.

Fig 23 indicates the mean daily intake measured for both types of feedblock (on a 3-day rolling mean basis) from 10 June when the cows started to consume the blocks to July 16. There was a progressive increase in intake throughout this period as the available grass decreased. On June 9 there was the first rainfall (21 mm) since transfer to grass and this did not seem to affect intake. Rain fell again on 16, 17, 18, 19 and 20 June (with 17 mm on 17 June) and this seemed to give a temporary increase from about 110 to 220 g feedblock DM/day. Thereafter no rain fell until the period 9 to 16 July. It would be difficult to conclude that this rain further increased block intake from the 420 g DM/day level it had reached, as the trend towards increased consumption was not changed. Eventually block consumption reached about 600 g DM/day but by that stage little grass remained and the cows had to be removed from the pasture.

The mean plasma magnesium and faecal chromic oxide concentrations at the various sampling periods are given in Table 36.

The lowest plasma magnesium concentration was 1.13 mg/100 ml for an individual cow (2 days post-turnout). There was a consistent but not significant decrease in mean plasma magnesium concentrations for both groups of cows at the sampling 2 days post-turnout. By 31 days post-turnout the mean plasma magnesium (2.04 and 1.96 mg/100 ml) had significantly exceeded ($P < 0.01$ and $P < 0.05$) the pre-turnout concentrations (1.72 and 1.70) mg/100 ml for the cows given R-MgP and RS feedblocks, respectively. The plasma magnesium concentrations were approximately maintained at these levels for the remaining sampling periods. At the 46 and 50 post-turnout samplings the mean plasma

Fig.23 Expt 11.1 Mean daily feedblock intake (g DM/head/day) for either R-MgP or RS feedblocks given to two groups of lactating suckler cows at spring grass. The date of turnout was 20 May 1975 and there was no block consumption during the initial 20 days at grazing.


BLOCK INTAKE
gDM/HEAD
R-MgP
RS MgO
1000
750
500
250
0
20
30
40
50
60
DAYS POST-TURNOUT

magnesium concentration for the cows given the R-MgP feedblock were significantly ($P < 0.05$) greater than for the cows given RS feedblock.

Table 36 Expt 11.1 Mean (± SE) plasma magnesium (mg/100 ml) and faecal chromic oxide concentrations (Range and CV%) for lactating beef cattle at spring grass

	Plasma magnesium mg/100 ml		Faecal chromic oxide g/100 kg DM					
	R-MgP	RS	R-MgP			RS		
			Mean	Range	CV%	Mean	Range	CV%
Pre-turnout	1.72±0.04	1.70±0.06						
Post-turnout (days) 2	1.64±0.05	1.54±0.06						
31	2.04±0.09	1.96±0.10	18	1- 48	92.7	10+	0 — 28	115.0
46	2.07±0.06	1.88±0.06*	55	4-192	90.1	13	3 — 41	88.2
50	2.05±0.03	1.86±0.07*	51	6-161	95.0	37	10 — 93	68.0
56	1.98±0.05	1.91±0.07	138	77-284	38.4	44	4 — 93	75.6

+includes 2 cows with no measurable quantity of chromic oxide in the faeces.

The concentration of chromic oxide in the faeces of the cows after they eventually started to consume feedblocks was highly variable (CV 38 to 115%). Absolute concentrations increased in parallel with mean feedblock intake, whilst individual variation generally decreased as feedblock intake increased. At the initial sampling for the cows given RS feedblock, 2 individuals had no measurable chromic oxide in the faeces.

There were no significant correlations between individual faecal chromic oxide and plasma magnesium concentrations.

Discussion

The results of the present experiment agreed with those of Expt 10.4, when similar supplement-type feedblocks (Rumevite Spring Block RHE and R-MgP) were given to lactating ewes, in addition to ample high quality spring grass. For both cattle and sheep there was a total refusal to consume the magnesium-containing feedblocks during the critical post-turnout period or under other equivalent circumstances when ad libitum high quality grass was available. Although it would be dangerous to place too much confidence in the results of this trial (the weather conditions may have been exceptionally dry) and those with lactating ewes (Expt 10.4), the failure to consume supplement-type feedblocks when other more palatable nutrients are available is consistent with Part A (Expt 8.2) of this section and severe indictment as to the suitability of such feedblocks, as magnesium carriers during the critical post-turnout period. In Expt 8.2 when sheep were given ad libitum dried grass cubes under housed conditions, a marked reduction in the consumption of RS feedblock occurred compared to when barley straw or hay was given.

With supplement-type feedblocks, similar to those used in the present experiment, it appears to be of little consequence what type of magnesium is included in the blocks due to the overwhelming unpalatability of other block ingredients and the unacceptability of the block in general, when spring grass is abundantly available. When the cows eventually started to consume the feedblocks given (10 June or thereabouts) after most of the grass had been consumed, the higher mean intake (36% and 300% more DM and Mg, respectively) of feedblock was recorded for the R-MgP block. It was unlikely that this difference would be solely due to the palatability of the different magnesium sources in the block, but probably affected difference in feedblock hardness (the NaCl inclusions were approximately similar for both block types).

As with the sheep experiments concerned with hypomagnesaemia, no clinical cases of tetany occurred. The cattle were slightly hypomagnesaemic even before turnout (1.70 mg Mg/100 ml) and the subsequent decline in plasma magnesium was slight (2 days post-turnout). The decline in plasma magnesium concentrations may have been greater if further blood samples at for example 7 and 14 days post-turnout had been obtained. Ritchie and Fishwick (1977) reported the details of plasma magnesium concentrations for 76 (dairy and beef) cows prior to turnout to spring grass. The mean plasma Mg was 2.20 $\pm$ 0.03 mg/100 ml, which was significantly ($P < 0.001$) greater than the pre-turnout values in the present study. Also in their report (Ritchie and Fishwick 1977), two similar beef-type cows on the same fields (1973) developed clinical signs of tetany characterised by plasma Mg concentrations of 0.27 and 0.32 mg/100 ml.

The eventually higher mean intake of magnesium from the R-MgP feedblock, than for the RS feedblock was reflected by the consistently higher plasma magnesium concentrations, for the cows given the former block. This indicates that the giving of supplementary magnesium as MgP could be effective in raising plasma magnesium status. Unfortunately, the general unpalatability and total unacceptability of the feedblocks used, relative to spring grazing, negated any effect of either MgO or MgP on magnesium status during the critical post-turnout period. It may be that the substitute-type feedblocks (e.g. W290(76) and Colborn-type blocks) are more suitable as carriers of magnesium compounds during the spring, as they are more palatable and allow a higher intake potential before constraints inherent in the block limit intake.

Expt 11.2 A comparative assessment of a Colborn experimental feedblock and concentrates, both containing magnesium phosphate to control hypomagnesaemia in cattle when transferred to grass

In Expt 11.1 suckler cows completely refused to consume supplement-type feedblocks (Rumevite) after being turned out to lush spring grass. It was not until mid June when grass quality and quantity decreased that feedblock consumption commenced appreciably. The possible reasons for this rejection of the block during the critical period were discussed, including a specific aversion to the type of feedblock used, which may not be common to more palatable block types. Therefore in Expt 11.2 a Colborn-type 'soft' experimental feedblock containing magnesium phosphate (C - MgP) (supposedly more palatable than magnesium oxide), instead of Rumevite blocks was given.

A comparative assessment of the suitability of this feedblock was made against a concentrate pellet containing MgP from the same source given in troughs.

Materials and Methods

The experiment was carried out during spring 1976 using the same cows and fields as described in Expt 11.1. Twenty one lactating beef cows (calved about 4 to 8 weeks) were divided into 2 groups of 11 and 10 animals.

The cows had received a diet of oat straw and approximately 2 kg of concentrate during the winter period, except for the 2-week period prior to turnout when grass silage and C - MgP feedblocks (39.8 g Mg, 23.0 g P, /kg DM) containing no chromic oxide were additionally made available.

On 14 May the cows were turned out to grazing. One group of cows was given access to field A (4.0 ha) and given a C - MgP feedblock (without a container) containing 8.67 g chromic oxide/kg DM.

The intake of the block was monitored by daily weighing and replaced when less than the preceeding days intake remained. The second group of cows was turned out into field B (2.8 ha) and given a constant daily allocation of 425 g DM/head (12 g Mg) of a concentrate pellet/120 g CP, 28.1 g Mg, 23.6 g P and 10.3 g chromic oxide (kg DM), containing MgP from a similar source as the C - MgP blocks. The concentrate was given in troughs once daily, with a space allowance of 180 cm/head (assuming access from both sides to the trough). The cows were alternated between the fields every 2 days.

Blood samples (for Mg, Ca and P) were obtained before turnout (Mg and P only) and 4 and 10 days post-turnout. Rectal grab samples (for chromic oxide) were obtained 4 and 10 days post-turnout. Grass samples (for Mg) were taken from each field at the time of turnout.

From 25 May to 7 June all 21 cows were in one group and given access to both fields. The giving of concentrates had been discontinued on 25 June. Rectal grab samples were obtained on the 7 June (23 days post-turnout).

On 8 June the experimental 'soft' C - MgP feedblock was replaced with the CC feedblock (Table 1 for proximate composition) containing 10.3 g chromic oxide / kg DM. The mean daily intake was monitored until 15 July, when both the cows and calves were rectally grab sampled.

Results

No clinical cases of hypomagnesaemic tetany occurred. During the initial 11 days of the experiment the mean daily temperature was 11°C and some rain fell on 10 of the days. Over the first few days 2 cows completely refused to consume the concentrates; subsequently all cows readily approached the troughs and apparently consumed some concentrate. The daily feedblock intake reached 150 g DM/head after 2 days and the mean intake over the 11-day period was 183 $\pm$ 24 g/head (min 114, max 324 g DM).

The magnesium and phosphorus contents of the herbage samples taken from fields A and B were 2.3 and 2.4 g Mg/kg and 3.2 and 2.9 P/kg, respectively.

When the cows were rectally grab sampled 4 days post-turnout (Table 37), the 2 cows which refused to compete at the troughs had no chromic oxide in their faeces. The CV given in the table does not include these individuals and is less than the corresponding value (68.6%) for the feedblock supplemented cows. If the 2 cows not consuming concentrate are included in the analysis the CV is increased to 70.4%, which exceeds the value for the block supplemented cows. One cow given the feedblock had a very low concentration (< 10 g/100 kg DM) of chromic oxide at the 4-day post-turnout sampling.

When the cows were sampled 10 days post-turnout, 2 cows given the feedblock had chromic oxide concentrations less than 6 g/100 kg faecal DM, compared to no individuals less than 27 g/100 kg faecal DM for the concentrate-supplemented group. The overall variation was also considerably less for the concentrate group (CV = 62%), than for the feedblock group (CV = 97.2%).

The mean plasma Mg, Ca and P concentrations are also given in Table 37. The plasma magnesium concentration (1.92 mg/100 ml) 4 days post-turnout was significantly ($P < 0.05$) below the pre-turnout level (2.30 mg/100 ml), for the concentrate supplemented cows only. However plasma P concentrations declined significantly ($P < 0.01$) for both groups after turnout. Ten days post-turnout the mean plasma Mg concentrations were similar to the pre-turnout levels. No individual magnesium values below about 1.5 mg/100 ml were recorded. There were no significant correlations between any of the blood parameters and faecal chromic oxide concentrations.

When all the cows were grouped together (25 May 7 June) and all given the C - MgP feedblock, the mean faecal chromic oxide (120 g/100 kg DM)

Table 37 Expt 11.2 Mean (± SE) plasma magnesium, calcium and phosphorus (mg/100 ml) and faecal chromic oxide concentrations (g/100 kg faecal DM) for the various samplings

	Feedblock				Concentrate			
	Magnesium	Calcium	Phosphorus	Chromic Oxide	Magnesium	Calcium	Phosphorus	Chromic Oxide
Pre-turnout	2.28±0.11		7.50±0.34		2.30±0.07		7.72±0.35	
4 days post -turnout	2.07±0.08	11.3±0.11	5.68±0.09	59 (68.6)$^{+}$	1.92±0.11*	11.4±0.15	5.42±0.37	87 (44.3)$^{++}$
10 days post-turnout	2.12±0.08	11.7±0.13	5.10±0.09	41 (97.2)	2.33±0.07	12.1±0.28	5.80±0.30	91 (61.7)

$^{+}$ CV%

$^{++}$ Two cows did not consume concentrates (CV = 79.4% if these individuals are included).

for the cows having 23-days previous experience of block consumption was twice the concentration (61 g/100 kg DM) of the cows with only 11 days previous experience on blocks. There was no difference however in the CV for faecal chromic oxide (72.6% and 76.9% for the experienced and less experienced cows, respectively). The climatic conditions were generally the same as before.

When the cows were given the CC feedblock instead of the 'softer' C - MgP feedblock, the mean daily intake decreased rapidly from about 500 to 170 g DM/head. Thereafter intake slowly increased to about 630 g DM/head as herbage availability decreased (by about 25 June the grass was in very short supply). The mean daily intake of both feedblocks (3-day rolling mean) is shown in Fig 24 over the experimental period. There were no significant correlations between rainfall or mean daily temperature and feedblock intake.

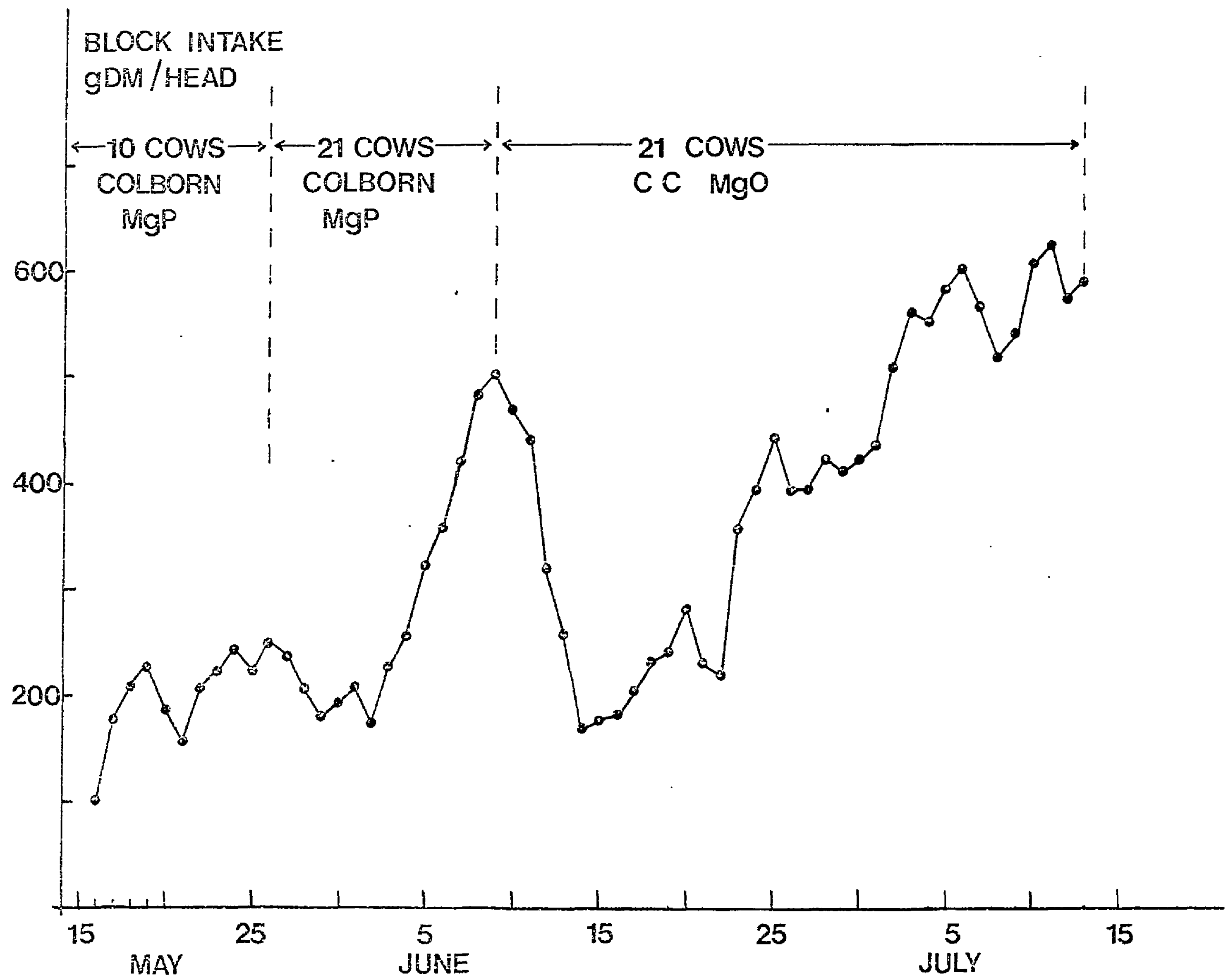
When both the cows and calves were rectally grab sampled on 15 July the mean chromic oxide concentrations were 100 and 54 g/100 kg faecal DM, respectively, with CV 86.7 and 192.9%. All cows and calves had some chromic oxide in their faeces.

Discussion

The soft experimental C - MgP feedblock was consumed during the critical post-turnout period, albeit in small quantities and therefore was far more suitable in this role than the rejected R-MgP or RS feedblocks, (Expt 11.1). The mean intake of magnesium from C - MgP feedblock ranged from a minimum of 4.5 to a maximum of 12.9 g/head/day (overall mean of 11 days = 7.3 g Mg/head) which is still considerably below the recommended prophylactic dose against clinical tetany (30 g Mg/head/day). Nevertheless, this additional magnesium would be very useful in situations where tetany was likely to occur.

There was appreciably more rainfall during the 11 days post-turnout

Fig.24 Expt 11.2 Mean daily intake (g DM/head/day) of Colborn-type feedblocks containing either MgP or MgO and given to groups of lactating suckler cows at spring grass. The date of turnout was 15 May 1976.



BLOCK INTAKE
gDM / HEAD
10 COWS
COLBORN
MgP
21 COWS
COLBORN
MgP
21 COWS
C C MgO
600
400
200
15
25
5
15
25
5
15
MAY
JUNE
JULY

in the present experiment than occurred in Expt 11.1, which may have partly stimulated the cows to consume feedblock. As in Expt 11.1 it was not until herbage availability decreased in late June and July that feedblock intake increased considerably. There was a striking similarity between the mean daily intakes of the R-MgP feedblock (Expt 11.1) and the CC feedblock (Expt 11.2), expressed as 3-day rolling means over an equivalent period in June and July in different summers. This indicates that at grazing, herbage availability is a far more important factor influencing absolute feedblock intake than characteristics inherent in the block type or intake restriction mechanism. Notwithstanding this, it appeared in the present experiment that a substitute-type feedblock (in this case, the Colborn type) is more likely to be consumed when herbage is abundantly available than the supplement-type (i.e. Rumevite) feedblocks.

Two of the cows given concentrates were very slow to compete at the troughs and refused the supplement for several days during the critical post-turnout period, which is clearly undesirable. One of these cows had a low plasma Mg concentration (1.5 mg/100 ml) when sampled 4 days post-turnout. However, unlike the feedblock situation these 'shy-feeders,' could be easily recognised and alternative measures taken to aid in the prevention of tetany if necessary. As in many other experiments in this thesis there was more individual variation in feedblock than concentrate intake, except in the situation where individual cows completely refused the concentrates.

There were again no clinical cases of hypomagnesaemic tetany, although several of the cows might be classified as mildly hypomagnesaemic (assuming that the normal range in plasma magnesium concentrations is 2.0 to 3.5 mg/100 ml). There was also no precipitous decline in mean plasma Mg post-turnout. The pre-turnout plasma Mg were significantly ($P < 0.001$) greater in this experiment than for the same cows during the preceeding year (Expt 11.1). One anomaly of the present experiment was the significant difference in mean plasma P concentration pre and post-turnout. This appeared to be mainly due to the high mean values pre-turnout (7.6 mg/100 ml) relative to the mean of 5.3 mg P/100 ml reported by Ritchie and Fishwick (1977). After turnout the plasma P concentrations in the present experiment were similar to those of the former workers.

The rectal grab sample taken when the calves were about 4 months old showed that they were consuming small and highly variable quantities of the feedblocks given, which may reflect a novelty interest only, possibly on appetite for the salt in the blocks.

The results of this experiment and Expt 11.1 suggest that the use of feedblocks as carriers of magnesium compounds as prophylactics against hypomagnesaemic tetany is at the best likely to be only partly reliable during the critical spring post-turnout period. The more palatable substitute-type feedblocks are more likely to be suitable magnesium carriers at such times than supplement-type blocks. Their effectiveness at other times of the year, particularly autumn and winter, requires further evaluation, but is also likely to be relatively ineffective in some situations. This was exemplified by the death of 2 cows in Section 2 (Expt 7.2) from suspected tetany during the autumn, when sole reliance for additional magnesium was placed on feedblocks.

An evaluation of feedblocks as carriers of specific nutrients such as magnesium compounds, anthelmintics, anti-warble dressing etc. indicates some severe limitations and deficiencies in the 'self-help' feedblock concept, as a suitable means of attaining a precise and uniform intake in any given situation. In Section 1 the considerable individual variation in feedblock intake was measured relative to 'hand-fed' supplements. In Section 2 the factors affecting total group intake and inter-day variation in feedblock intake were described. In Section 3 (Part C) the inability of individual ruminant animals to consume a specific nutrient (magnesium) (albeit not in a totally critical situation where clinical tetany was occurring) in constant reliable amounts in various circumstances was emphasised.

In conclusion a 'self-help' system of giving specific nutrients such as in feedblocks is likely to be inferior to individual dosing methods or 'hand-feeding' because of the uncertain nature of the former method. There was no evidence to suggest that magnesium offered in a feedblock was consumed according to need.

SECTION 4

THE EFFECT OF FEEDBLOCKS ON THE UTILISATION OF ROUGHAGES PARTICULARLY THOSE OF POOR QUALITY

Introduction

The principal nutritional justification for using the supplement-type and to a lesser extent the substitute-type feedblocks, relies on their claimed ability to enhance the utilisation of roughages, particularly those of poor quality. Poor quality roughages are usually assumed to be those deficient in nitrogen (CP $<$ 50 to 60 g/kg DM) and/or phosphorus and have high crude fibre contents. Examples of these poor quality roughages commonly given to ruminants in the UK are the cereal straws (usually barley and oat), many hay samples, some silages and winter grazings, particularly in hill areas. The latter situation is complicated by the degree of selectivity exhibited by the grazing ruminant (especially the hill ewe), resulting in the consumption of a diet of higher quality than the average composition of the material available. The feature common to all these poor quality roughages is that digestibility and consequently voluntary intake is very low. Blaxter, Wainman and Wilson (1961) showed that the voluntary intake of sheep given a series of long roughages, was related to this apparent digestible energy values. The voluntary intake of three hays of widely different composition was also related to their rate of passage through the gut. Essentially similar results relating voluntary intake to the apparently digestible energy content of the roughage were also found with steers (Blaxter and Wilson 1962). Therefore any improvement in digestibility should result in an increased nutrient intake by the animal.

Feedblocks might theoretically improve roughage digestibility and hence intake in several ways depending on the circumstances.

i) The alleviation of a specific mineral or vitamin deficiency

A specific deficiency of a mineral (e.g. phosphorus) may limit roughage intake due to a lowered digestibility, as demonstrated by Little (1968) and Playne (1969) with sheep given low-phosphorus lucerne and Fishwick, Fraser, Hemingway, Parkins and Ritchie (1976) with beef cows given straw. A very high proportion of hays and straws have been shown (e.g. Hemingway, Macpherson, Duthie and Brown 1968; Hemingway 1971) to provide much less phosphorus than has been recommended (ARC 1965) for the maintenance of adult cattle. The provision of supplementary phosphorus in feedblocks would alleviate this deficiency and result in improved roughage utilisation, if the animals consumed sufficient of the feedblock. Other specific dietary deficiencies would be rectified accordingly.

ii) The alleviation of a nitrogen deficiency

Virtually all feedblocks contain supplementary nitrogen (either preformed protein or NPN, usually urea). In many areas throughout the world, including the United Kingdon, there is an abundant supply of poor-quality roughages which may be deficient in several nutrients perhaps the most important of which is nitrogen. The addition of protein or NPN should in theory improve their nutritive value.

Increases in voluntary intake of low-protein roughages given to ruminants by addition of urea to the diet have been obtained by many workers (e.g. Clark and Quinn 1951; Franklin, Briggs and McClymont 1955; Morris 1958; Beames 1959; Williams, Pearce, Delany and Tribe 1959; Coombe and Tribe 1963). An increased rate of digestion (Coombe and Tribe 1963) and rate of passage of digesta through the digestive tract (Coombe and Tribe 1963; and Pieterse, Lesch and von Schalkwyk 1963) have been reported following the addition of urea to diets of low nitrogen roughages. Some workers have also recorded increased digestibility resulting from additions of urea to the diet (e.g. Beames 1959; Elliot 1960; Campling, Freer and Balch 1962; and Smith 1962) but other workers have not been able to demonstrate a significant improvement in digestibility (Dinning, Briggs and Gallup 1949; Clark and Quinn 1951;

Thompson, Graf, Eheart and Holdaway 1952; and Williams et al. 1959). At high rates of urea supplementation a decline in both intake and rate of passage can occur (Coombe and Tribe, 1963).

The very limited amount of published literature on the effect of giving blocks containing supplementary nitrogen on the performance of cattle and sheep has been reviewed in the Introduction of this thesis. In many of these reports roughage intake was not recorded, although a response to nitrogen supplementation was sometimes measured, indirectly, in terms of decreased live-weight loss.

In one report, Altona (1966) indicated that when cattle were given four hays ranging in crude protein content from 56 to 96 g/kg, the daily live weight response to urea supplementation progressively decreased from + 0·62 to + 0·12 kg/day.

When roughage intake was recorded, any response to nitrogen supplementation seemed to depend on the nitrogen composition of the roughage. For example, no effect on hay intake (101 g CP/kg) with cattle was obtained by Pearce and Raven (1973), when given block supplements containing either urea or groundnut as nitrogen sources, whilst Beames (1963) reported increases in hay intake (35 g CP/kg) of 29 and 45% for cattle aged 26 and 14 months, respectively.

Campling, Freer and Balch (1962) showed that the consumption of oat straw by adult cows was increased by 40% when 75 or 150 g urea was infused continuously into the rumen. In addition, organic matter digestibility was increased, as were the rate of passage of feed through the digestive tract and digestibility of cotton threads suspended the rumen. Continuous infusion and the use of feedblocks as nitrogen (urea) supplements may have a common feature, that of frequency of urea intake. In many circumstances however the frequent ingestion of urea from feedblocks may be a potential rather than actual occurrence. Tait, Milne and Russel (1976) showed that the addition of 0·5 g N/day (as caesin or urea) resulted in a mean increase in heather (Calluna

Vulgaris) intake of the order of 29%, when continuously infused. An additional 1·5 and 3·0 g N further increased intake by about 7 and 14%, respectively. Digestibility was increased by 36, 38 and 40%, respectively, for the 0·5, 1·5 and 3·0 g levels of nitrogen supplementation.

One of the proposed advantages for giving supplementary urea on a 'self-help' basis, such as in feedblocks or liquids, is that it is claimed, that urea is utilised far more efficiently when consumed little and often, compared to when given once daily in a concentrate feed. In vitro work by Bloomfield, Garner and Muhrer (1960) indicated that the rate of urea hydrolysis was 4 times greater than the corresponding uptake of ammonia nitrogen by the rumen micro-organisms. In a subsequent in vivo trial using wether sheep, Bloomfield, Welsch, Garner and Muhrer (1961) reported increased nitrogen balance, increased whole blood albumin and lower blood urea values when a diet containing 32 g urea/kg was offered 16 times/day compared with 2 times/day.

A similar response to frequent administration of urea-containing foodstuffs was reported by Campbell, Howe, Martz and Merilan (1963). These workers reported that heifers given a diet containing 33 g urea/kg, 6 times/day had a 25% greater daily live-weight gain, compared with animals given the same quantity of supplement twice daily.

Other workers have found no response to infusions or frequent intakes of urea. Minson and Pigden (1961) reported no consistent effect on the digestibility of chopped oat straw with the continuous infusion of urea but the voluntary intake was decreased by 12%. Goodrich, Meiske and Gharib (1972) found no advantage for giving urea frequently in terms of increased utilisation.

One of the objectives of Section 4 was to assess the importance of frequency of urea intake from feedblocks in relation to roughage utilisation. Also it was intended to examine the behavioural aspects of block feeding with housed cattle, with emphasis on number, duration and distribution of visits to a feedblock during any 24-hr period.

iii) The provision of additional energy

A further possible mechanism whereby feedblocks might enhance roughage utilisation, is possibly via the provision of additional energy. Energy in the form of carbohydrate may operate beneficially in two inter-related ways, both concerned with the synthesis of microbial protein. The function of carbohydrates on converting ammonia to microbial protein is to make energy and carbon skeletons available for microbial synthesis. The energy required for microbial protein synthesis has been reviewed by Thomas (1973). Hungate (1966) estimated that 1·1 g of microbial nitrogen is assimilated for each 100 g of carbohydrate fermented under in vitro conditions. Bloomfield et al. (1964) reported that 55 g of carbohydrate were required for each gram of nitrogen fixed. After allowing for a 10 to 12% loss of energy in methane about 66% of the food energy is contained in acetic, propionic and butyric acids and is available to the host through tissue oxidation.

Carbohydrates differ widely in their effectiveness of enhancement of microbial protein synthesis (see review by Helmer and Bartley 1971). The least effective carbohydrate seems to be cellulose; the most effective starch. Starch is also superior to molasses or simple sugars. The low efficiency of utilisation of dietary nitrogen, when molasses is used as a major carbohydrate, appears to be mediated via its effect on the rumen fermentation pattern. Sutton (1968 and 1969), using both in vitro and in vivo techniques has established that fermentation of soluble sugars, glucose, fructose and sucrose tends to favour butyrate production. Under a butyrate fermentation pattern, when molasses is the major carbohydrate source, the type of bacteria may influence the efficiency of utilisation of dietary nitrogen. The species of bacteria (Bacteroides amylophilus and Selenomonas ruminantium) with the highest efficiency of microbial protein production may be absent under these conditions

(Karalazos and Swan, 1976). Jackson, Rook and Towers (1971) reported that there was a highly significant relationship between abomasal output of nitrogen and the proportion of propionic acid in the rumen volatile fatty acids and also an inverse relationship with the proportion of butyric acid. Faichney (1965) showed that sucrose did not improve nitrogen utilisation in sheep when straw diets were supplemented with urea.

Tait et al. (1976) supplemented heather diets given to sheep with continuous infusions of either energy alone or energy and nitrogen combined. The energy source used was sucrose. The addition of 50 g sucrose alone increased the intake of heather by about 43% and the digestibility by about 10%, but 150 g sucrose decreased both intake and digestibility of heather by about 14% in each case. The addition of 50 g sucrose plus 0·5 g nitrogen (urea) increased the intake and digestibility by 33% of 17% respectively. 150 g sucrose plus 0·5 g nitrogen gave no further response. The addition of 50 g sucrose to 3·0 g nitrogen increased the intake and digestibility of heather by 12 and 5%, respectively, and 150 g sucrose plus 3·0 g nitrogen gave no additional response in terms of intake, but increased the digestibility of heather by 11%.

Hemsley and Moir (1963) reported that 30 g urea/kg diet increased the voluntary intake of hay (46 g CP/kg) by 37% and DM digestibility by 13%. When 100 g molasses/kg diet were additionally given no effect on digestibility was measured and hay intake was 46% greater than when unsupplemented.

Therefore the effect of sucrose and other sample sugars on urea and hence roughage utilisation appears to be variable and inferior to the effect of starch. Of the feedblocks studied in this thesis only the W290(74) and W291(74) blocks contained appreciable amounts of molasses (about 300 g/kg). The carbohydrate sources in the other blocks were essentially cereal grains (starch).

iv) The provision of additional sulphur

All proteins contain sulphur in the form of sulphur containing amino acids (cysteine and methionine). When supplementary protein is given as urea, together with an energy source, it is possible that a potential deficiency of sulphur might occur. The extent of this potential risk of a sulphur deficiency depends upon the sulphur levels in the other dietary constituents.

The manufacturers of the Colborn range of feedblocks emphasise the importance of adequate sulphur in the diet for maximum protein utilisation, whether this is derived from roughage or other foodstuffs (e.g. feedblocks). Hume and Bird (1970) reported an increase in microbial protein production from 82 to 94 g/day, when dietary sulphur was increased from 0·61 to 1·95 g/day, but no additional response was found on increasing the sulphur intake to 3·42 g/day. Gosset, Perry, Mohler, Plumlee and Beeson (1962) observed effects of sulphur additions at levels of urea supplementation in excess of 60% of the dietary nitrogen. Therefore, under UK conditions where there is no evidence of sulphur deficiency in herbage, it appears to be rather academic whether sulphur supplementation is made unless the NPN content of the total dietary nitrogen exceeds about 50%.

v) The provision of 'unknown' rumen stimulatory factors

Some manufacturers include distillery by-products in their feedblocks for various reasons. These include dried distillers solubles (DDS), (270 g CP, 40 g CF, 70 g EE, 90 g Ash, 530 g NFE/kg DM), which has been shown to enhance cellulose digestion in vitro (Potter, Little and Mitchell, 1966). Several organic compounds have been shown to stimulate cellulose digestion by rumen micro-organisms in vitro, and some have been related to the stimulatory activity of certain footstuffs including DDS. For example, Dehority, Bentley, Johnson and Moxon (1957) reported that the stimulatory activity in yeast, caesin and alfalfa extract was due to some amino acids, particularly proline. Potter et al. (1966) found that proline content alone of corn dried distillers solubles was not the only criterion of stimulatory activity. They hypothesised that valeric acid was the most important compound in stimulating cellulose digestion by rumen micro-organisms and that in foods not containing valeric acid per se, the stimulatory activity was due to the conversion of proline to valeric acid.

The effect of giving dried distillers solubles in vivo has been inconsistent. Ely, Little and Spears (1975) gave lambs, diets containing 33 g urea/kg and no DDS, 29 g urea and 50 g DDS/kg and 24 g urea and 100 g DDS/kg. The ruminal cellulose digestion was 20, 30 and 31%, respectively. There was no difference in abomasal recovery of nitrogen for the 3 diets (12·7 to 13·0 g N/day). In a second experiment 4 diets containing either urea, urea plus 100 g DDS/kg, caesin or gelatin were given and the effect on cellulose digestion measured. The ruminal cellulose digestion was 18, 23, 17 and 14%, respectively and abomasal recovery of nitrogen 9·8, 10·0, 11·4 and 9·0 g N/day. When cellulose and nitrogen digestion was considered throughout the whole digestive tract, the lowest efficiency for both parameters was obtained for the urea alone diet. (Cellulose digestion 32, 45, 46 and 38; nitrogen digestion 41, 52, 53 and 52%, respectively). No statistical treatment was applied to the results in this work and the number of lambs per treatment was not given.

One particular feedblock manufacturer (Rumenco Co. Ltd.), markets a range of block products (Rumevite, for example RS and RHE), containing a distillery by-product known as EC feed (distillers molasses dried solubles). EC feed is a very hygroscopic, highly viscous, spray dried brown powder. This product is extensively claimed to improve the utilisation of roughages alone by amounts up to 50% (e.g. Scottish Farmer, 17 Nov 1973). The chemical composition of EC feed is 92 g CP, 1 g CF, 1 g EE, 332 g ash, 554 g NFE/kg DM. (The composition of the ash is 59 g Ca, 3 g P, 10 g Mg, 40 g Na and 80 g K/kg) with a pH of 10 to 11. The only published results on the effect of Rumevite ingredients, including EC on roughage utilisation are a small scale trial carried out by Unsworth, Lamb and Armstrong (1966). EC feed significantly depressed the dry and organic matter digestibility of hay (55 g CP, 312 g CF/kg DM) and of the other ingredients studied, only urea (which significantly improved nitrogen digestibility) had any effect on the utilisation of barley straw or hay.

One of the objectives of the present Section was to evaluate in detail the effect of Rumevite ingredients, particularly EC feed, on the utilisation of roughages.

A The effect of feedblocks on the utilisation of straw diets by inwintered cattle

Three experiments were carried out with inwintered cattle with the intention of comparing feedblocks and concentrates as supplements to diets of cereal straw. In the first experiment a behavioural trial using time lapse photography was also carried out, to ascertain the frequency, duration and distribution of visits to a feedblock during a 24-hr period.

Expt 12.1 A comparison between feedblocks and individually allocated concentrates

Materials and Methods

Twenty four Hereford cross steers and heifers, weighing 80 to 127 kg, were divided into 2 groups of 12 (H and L), on the basis of live weight (group H were the heavier animals). Each group was further subdivided into 3 groups of 4 animals, according to sex and live weight, giving a duplicated 3 x 3 Latin square design. The cattle were housed in an open-fronted building and bedded on limited amounts of poor quality straw.

The groups of cattle in each Latin square received one of the following supplements in random sequence.

A) A W291(74) feedblock given in a wooden container, affording protection to the block sides and corners, with the intention of restricting mean feedblock intake to less than 1 kg/head/day.

B) An allocation of barley-urea cubes given individually, using self locking yolks, supplying an equivalent amount of DE and DCP/head/day commensurate with the mean amount of block consumed during the preceeding 24 hours. (Each gram of urea was assumed to supply 2·8 g CP).

C) An allocation of barley cubes given individually and supplying an equivalent amount of DE as A) and B), but no additional urea.

The barley-urea and barley cubes both contained vitamin and mineral inclusions. The chemical composition of the block and other supplements are given in Table 38. The intake of the W291(74) feedblock was monitored by daily weighing and a new block substituted when less than the previous days consumption remained.

In addition oat straw was given ad libitum to all groups from Norwegian-type hay boxes (these were replenished twice daily). The group intakes of straw were recorded over a 7-day period, following 10 days of introduction to the treatments. Samples of oat straw were obtained every second day for chemical analysis (Table 38). A separate DM determination was carried out on the straw residues at the end of each treatment period.

Chromic oxide was included in the supplements at the levels outlined in Table 38. Rectal grab samples were obtained twice daily (08.00 and 16.00 hr) from each animal during the final 7 days of the treatment periods.

Table 38. Expt 12.1. Composition of the foods given (g/kg DM)

	W291(74)	Barley-urea cube	Barley cube	Oat straw
CP	226.0	315.0	117.8	28.0
CF	16.1	54.8	42.6	416.3
EE	4.3	14.0	18.3	8.4
Ash	252.4	39.0	25.2	28.8
Ca	46.7	5.0	6.7	3.0
P	5.6	4.0	4.1	0.3
Cr_2O_3	2.40	3.48	3.74	-

Time lapse photography (intervals of 68 seconds between frames) was employed to record the behaviour of the cattle given feedblocks during the experiment. Special reference was placed on the frequency, duration and distribution of visits during each 24-hr period.

Blood samples (for urea) were obtained on the penultimate day of each treatment period at times before giving the concentrates and 4 hours later (12.00 hr).

The DE and DCP contents of feedblock (10·4 MJ and 174 g DCP/kg) and barley cube (14·2 MJ and 86 g DCP/kg) used in the experiment, were estimated using wether sheep in metabolism cages. The digestibility by difference technique (Page 74)was used for the W291(74) feedblock. In practice, the barley-urea cube supplied slightly less DE than anticipated due to the diluting effect of the urea inclusion on DE content. This amounted to an under allocation of about 6%. The difference in DM coefficients of the W291(74) feedblock (0·83) and the barley-urea and barley cubes (about 0·85) was not considered important.

Results

All animals lost weight during the experiment (1 to 23 kg) with a mean loss of 10·5 kg over the 51 days of the experiment. The W291(74) intakes and consequent allocations of barley-urea and barley cubes are summarised in Table 39.

Table 39. Expt 12.1. Mean (± SE) daily supplement intakes (kg/DM head)

	Group H		Group L	
	W291(74)	Barley or Barley urea	W291(74)	Barley or Barley urea
Period 1	1.27 ± 0.15	0.93	0.83 ± 0.08	0.61
Period 2	0.68 ± 0.10	0.50	0.81 ± 0.01	0.59
Period 3	1.07 ± 0.13	0.78	0.98 ± 0.07	0.72
Mean	1.00	0.74	0.87	0.64

The heavier cattle consumed most feedblock in 2 of the 3 periods and about 15% more overall. The mean voluntary oat straw intakes for the

3 treatments are given in Table 40. The amount of straw consumed by the barley-urea supplemented cattle (4.28 kg DM/head/day) was significantly ($P < 0.01$) greater than the feedblock or barley alone supplemented groups (3·77 and 3·59 kg DM/head/day, respectively). The feedblock supplemented cattle consumed 5% more straw on average than the barley alone treatment, but the difference was not statistically significant. The increase in straw intake for the heavier (group H) cattle, given barley-urea cubes, was particularly large (27%) relative to barley alone. The corresponding increase for group L cattle was 12%.

Table 40. Expt 12.1. Mean daily voluntary straw intake (kg DM/head)

	Group H			Group L		
Treatment	W291(74)	Barley-urea	Barley	W291(74)	Barley-urea	Barley
Period 1	3.41	4.41	2.93	2.95	3.53	3.01
Period 2	4.09	4.50	4.10	3.49	4.35	3.91
Period 3	4.40	4.65	3.69	4.26	4.24	3.90
Mean	3.97	4.52	3.57	3.56	4.04	3.61

Combined treatment means	W291(74)	Barley-Urea	Barley	SED[+]
	3.77	4.28	3.59	0.10

Significance; W291(74) v. Barley, NS; Barley-urea > W291(74) or Barley alone **

+ Standard error of difference between 2 treatment means.

The plasma urea concentrations (Table 41) confirmed the upgraded nitrogen status of both the W291(74) and barley-urea supplemented cattle, compared to those given no extra urea. When the cattle were sampled before giving the concentrate allocations, the W291(74) treatment gave a significantly ($P < 0.05$) higher plasma urea concentration than the barley-urea treatment. This difference disappeared when the cattle were again sampled 4 hours after receiving the daily barley-urea allocation, due to a significant ($P < 0.001$) increase in plasma urea for the barley-urea treatment. No significant increases in plasma urea concentration were recorded for either the W291(74) or barley alone treatment between the two sampling periods.

Table 41. Expt 12.1. Mean plasma urea concentrations (mg/100 ml)

	W291(74)	Barley-urea	Barley	SED	Level of Sig.
Pre-feeding (08.00 hr)	24.3	16.9	7.8	1.8	W291(74) > Bu* W291(74), Bu > B***
Post-feeding (12.00 hr)	25.4	23.9***	7.6	1.7	W291(74) v. Bu NS; W291(74), Bu > B***

Table 42 contains mean faecal chromic oxide concentrations for the treatments given. The CV for faecal chromic oxide (31.5%) was significantly ($P < 0.01$) greater, when the cattle were given W291(74) in groups, compared to receiving barley-urea or barley allocations individually (13·0 and 10·1%, respectively).

Table 42. Expt 12.1. Mean (and CV%) in faecal chromic oxide concentrations (g/100 kg DM)

	W291(74)		Barley-urea		Barley	
	H	L	H	L	H	L
Period 1	80(15.4)	75(42.6)	111(8.6)	113(31.0)	105(12.8)	110(7.8)
Period 2	45(26.2)	68(40.6)	57(9.4)	86(7.0)	64(15.2)	32(11.6)
Period 3	76(31.2)	87(33.0)	117(12.8)	111(9.0)	105(6.8)	105(6.0)
Mean CV	24.3	38.7	10.3	15.7	11.6	8.5
Mean CV for both groups H and L	31.5		13.0		10.1	SED = 3.82

Significance; W291(74) > Bu, B** Bu v. B, NS

Only on one occasion when group L calves received barley-urea cubes in Period 1, was the CV for faecal chromic oxide concentration (31.0%) for concentrates greater than those for blocks (15.4 to 42.6%).

There were significant, ($P < 0.001$), positive correlations ($r = 0.71$ and 0.77) between individual faecal chromic oxide concentrations and plasma urea concentrations for the W291(74) supplemented cattle at 08.00 and 12.00 hr. These relationships were represented by linear regression equations which were at 08.00 hr, $y = 1.43x + 48.7$, SE of $b = \pm 0.63$ and at 12.00 hr, $y = 1.49x + 34.1$, SE of $b = \pm 0.55$, where y = chromic oxide concentration (g/100 kg DM) and x = plasma urea concentration (mg/100 ml).

The correlations ($r = 0.58$ and 0.73) were also significant ($P < 0.01$ and $P < 0.001$) between faecal chromic oxide and plasma urea concentrations (at the 08.00 and 12.00 hr samplings, respectively), when the barley-urea concentrate cubes were given. These relationships were also represented

Table 43. Expt 12.1. The behaviour of cattle consuming W291(74) feedblocks indoors (mean, 4 animals)

	Group H (Period 2)				Group L (Period 1)			
	Day 1	2	3	Mean	Day 1	2	3	Mean
Visits to block head/day	12	17	21	17	27	24	21	24
Time spent at block (mins/day)	34	77	72	61	76	61	69	69
Mean duration of each visit(mins)	2.83	4.53	3.43	3.60	2.82	2.54	3.29	2.88
% Distribution of visits throughout a 24-hour period								
20.00-08.00	4.2	25.5	17.0	15.6	19.6	19.6	19.2	19.5
08.00-12.00	29.2	31.4	22.1	27.6	23.0	31.0	24.0	26.0
12.00-16.00	31.3	17.6	33.0	27.3	25.9	16.5	12.0	18.1
16.00-20.00	35.5	24.5	26.8	28.9	31.5	32.9	44.6	36.4
% Distribution of time spent at the block during a 24 hr-period								
20.00-08.00	5.7	18.4	17.9	14.0	19.4	19.2	19.3	19.3
08.00-12.00	30.9	40.9	20.9	30.9	21.1	24.1	30.4	25.2
12.00-16.00	31.6	14.5	33.4	26.5	24.0	25.9	15.6	21.8
16.00-20.00	31.8	26.2	27.8	28.6	35.5	30.8	34.7	33.7

by linear regression equations which were at 08.00 hr sampling, $y = 1{\cdot}64x + 71{\cdot}3$, SE of $b = \pm 1{\cdot}03$ and at 12.00 hr, $y = 1{\cdot}76x + 56{\cdot}2$, SE of $b = \pm 0{\cdot}73$. There were no significant correlations between the faecal chromic oxide and plasma urea concentrations at the two sampling times for the cattle given barley alone cubes.

Due to the vast amount of data generated by the time lapse photography studies, it was only possible to examine two films in detail, covering two 3-day periods. The films chosen were for group L cattle in Period 1 and for group H cattle in Period 2. A summary of the results obtained is given in Table 43. The cattle in group L made 41% more visits (24) to the block, than the group H cattle (17) studied in Period 2. There was however very little difference in total time spent at the block during a 24 hour period, averaged over 3 days (61 and 69 mins). The heavier (group H) cattle stayed slightly longer at each visit to the block (3·60 v. 2·88 mins). The cattle in both groups spent significantly ($P < 0{\cdot}001$) more time at the block and made significantly ($P < 0.001$) more visits during the 12-hr period 08.00 to 20.00 hrs (day time), compared to the 12-hr period 20.00 to 08.00 hrs (night time).

For both groups of cattle, less than 20% of visits to the block were in the period 20.00 to 08.00 hr. The mean DM intakes of feedblock/visit were 40 and 35 g/head for the group H and L cattle, respectively. The amounts of urea consumed/visit were calculated to be about 2·4 and 2·1 g/head. There were no significant correlations between individual faecal chromic oxide concentrations and any of the behavioural parameters examined. This was probably due to the small number of individual cattle studied (8 in total).

Discussion

The results indicated that giving W291(74) feedblocks in a group situation stimulated a lower mean voluntary oat straw consumption, compared to an equivalent amount of DE and DCP offered individually as a barley-urea cube once daily. The feedblock supplement gave a mean daily intake of straw only slightly greater than the barley cube (given individually), which supplied no additional nitrogen. The most likely explanation for this difference in oat straw consumption appears to reflect how the supplements were given, rather than differences inherent in their nutritive value. However, a depressive effect on voluntary straw intake and/or digestibility of one or more of the block ingredients cannot be ruled out.

The intake of the W291(74) feedblock was controlled partly by physical hardness and partly by the unpleasant taste of one or more of the block ingredients. Calcium sucrosate, a chemical formed when molasses and calcium hydroxide interact, is instrumental in imparting both hardness and unpleasant (bitter) taste into the block. The effect of calcium sucrosate on roughage intake and digestibility has not been studied.

The W291(74) feedblock was given ad libitum on a group basis, whilst the barley-urea and barley allocations were given individually. This difference in method of offering the supplements was reflected in the significantly higher variation in faecal chromic oxide concentrations (supplement intake) for the cattle given blocks. There was also more variation in plasma urea concentrations for the cattle given blocks, than for the other two treatments. Faecal chromic oxide and plasma urea concentrations were significantly correlated for both the block and barley urea treatments.

It is therefore possible that some of the individual cattle given blocks, only consumed small amounts of supplementary nitrogen and consequently manifested only a minimal response, in terms of increased oat straw intake. Conversely, the cattle with the higher individual block intakes would consume considerable quantities of supplementary nitrogen, which would result in no further response in oat straw intake once the crude protein in the overall diet reached say about 50 to 60 g/kg.

The cattle receiving the barley-urea and barley allocations consumed approximately the same amount of DE and DCP in total as those given blocks, but it was known that each individual animal received an equal share of the supplement, sufficient to rectify the nitrogen deficiency in the straw. The crude protein in the total diet for all individuals was about 70 g/kg (4·28 kg oat straw, 28 g CP/kg = 120 g CP; 0·74 kg barley-urea pellets, 315·0 g CP/kg = 233 g CP). That supplementary nitrogen was beneficial under the experimental conditions was confirmed by the almost 20% mean difference in straw intake between the barley-urea and barley alone treatments. The heavier cattle (group H) showed a greater response to the barley-urea supplement than the lighter (group L) animals.

The time lapse photography data showed that frequency of block intake can be very high (17 to 24 visits/day) for housed cattle and theoretically an increase in NPN utilisation might be expected, perhaps resulting in increased digestibility and/or roughage intake. Any beneficial effect of frequent urea intake seemed to be overshadowed by the differences due to how the supplements were given, resulting in the differences in distribution between individuals as described. In both films examined, the cattle on average spent about one hour/day overall at the feedblock, with a range for individuals of 49 to 95 minutes. Most of the activity (> 80%) at the blocks was recorded during the day time (08.00 to 20.00 hr). The onset of activity may have been determined by the weighing of the block and general disturbance created by the stockfeeder. In general the behaviour of the heavier (group H) and lighter (group L) cattle during the periods studied was very comparable.

In many practical situations concentrate supplements are allocated on a group basis where competition is important. In Section 1 the degree of individual variation in feedblock intake was shown to be significantly greater than when the same groups of cattle were given equivalent DM as concentrates in troughs. Therefore if the distribution of the total supplement allocated is important, as this present experiment suggests, feedblocks may be inferior to 'hand-fed' supplements. In the following experiment a comparison was carried out with cattle given feedblocks or 'hand-fed' supplements, competitively.

Expt 12.2. A comparison between feedblocks and concentrates given competitively

The objective of Expt 12.2 was, firstly, to make a comparative assessment, in terms of individual intake variation of 'self-help' feedblocks and 'hand-fed' supplements given competitively and supplying equivalent amounts of DM or DE and DCP. Secondly, to examine the effect on voluntary straw intake of any differences in supplement intake variation between the contrasting supplementation techniques.

Materials and Methods

Twelve (Hereford cross) cattle (3 steers and 9 heifers) of mean live weight 279 kg were divided into 2 groups of 6 animals (A and B) on the basis of sex and live weight. The animals were housed in an open fronted building on 4 January 1976 after previously being outwintered.

The DE and DCP contents of the W291(74) feedblock were as used in Expt 12.1. The DE of the barley used was assumed to be 16·9 MJ/kg ($DE = \frac{13\cdot7}{0\cdot81}$, MAFF et al. 1975). The DCP of barley was taken to be 82 g/kg (MAFF et al. 1975).

The following treatments were given in successive 17-day periods.

Period 1

Group A received W291(74) feedblocks ad libitum in a wooden container. Group B received an equivalent amount of DE and DCP in a barley-urea cube (once daily), in troughs with a space allowance of 60 cm/head. The amount of barley-urea given daily was adjusted to coincide with the mean intake of DE and DCP from the block during the previous 24 hours. As the DE of the blocks (10·4 MJ/kg) was considerably below the DE of the barley-urea concentrates (DE of barley = 16·9 MJ/kg), 1 kg of W291(74) DM was equivalent to 0.67 kg DM of the barley-urea concentrate. The barley-urea concentrate contained about 66 g urea and about 16 g minerals/kg.

Period 2

As for Period 1 but with the supplements reversed.

Period 3

Group A cattle received 0·64 kg DM/head of barley-urea concentrate in one daily feed, with a similar trough space allowance as before. Group B cattle received a similar daily allocation of 0·64 kg DM/head of barley-urea concentrate but divided into 2 feeds (08.00 and 16.00 hrs), each of 0·32 kg DM/head.

Period 4

Both groups of cattle received an equivalent amount of DM as barley-urea concentrate, commensurate with the mean daily DM intake of W291(74) by the respective groups in Periods 1 and 2. This amounted to 0·51 and 0·95 kg DM/head for groups A and B, respectively. These allocations were given once daily (08.00 hr) with the same trough space allowance as before.

The composition including chromic oxide inclusion of the W291(74) feedblock and barley-urea concentrate is given in Table 44. In Periods

1 and 2 the feedblock intake was measured by daily weighing. In the present experiment it was desired for the cattle to gain live-weight. (In Expt 12.1 all animals lost weight on W291(74) blocks and straw alone), therefore each animal was additionally given 0.85 kg DM/head/day of barley in individual feeders.

In all the treatment Periods oat straw was offered ad libitum in Norwegian-type hay boxes. The amount of straw consumed was recorded over the final 7 days of each period. Samples of the straw were obtained every second day for DM analysis (Table 44). A separate DM determination was carried out in the straw residues upon completion of each period.

Rectal grab samples (for chromic oxide) were obtained once daily (09.00 hr) over the final 7 days of each period. The cattle were weighed at the end of each Period.

Table 44. Expt 12.2. Mean composition of foods given (g/kg DM)

	W291(74)	Barley-urea concentrate	Oat straw
CP	236.9	257.2	31.2
CF	28.0	37.0	428.4
EE	7.3	9.9	12.5
Ash	249.0	52.7	57.5
Ca	46.7	8.43	3.6
P	5.60	2.44	1.04
Chromic oxide	2.40	5.14	-

Results

All cattle gained live weight during the experiment. The highest weight gains (0·55 kg/day) were recorded when the most DE and DCP were given (Period 4), equivalent in terms of DM to the intake from W291(74) feedblocks. The lowest live-weight gains (0·21 kg/day) were recorded when the cattle received an equivalent amount of DE and DCP as barley-urea concentrate, commensurate with the intake of DE and DCP from the block.

Details of mean live-weight gain, supplement and oat straw intakes and faecal chromic oxide concentrations are given in Table 45 for the various treatment periods. The cattle consumed most oat straw (5·08 kg DM/head/day) when the barley-urea concentrates were given, commensurate with DM consumed from the W291(74) block (Period 4). The lowest mean consumption of oat straw (4·27 kg DM/head/day) was recorded during Period 3, when the cattle received 0·64 kg/head of the barley-urea concentrate in a single or twice-daily feed. There was little difference in mean voluntary straw consumption (4·74 and 4·50 kg/DM/head/day), when an equivalent amount of DE and DCP was consumed by a group of cattle (6) from either a feedblock or barley-urea concentrate, both given competitively.

The CV for cattle given feedblocks (29·6 and 38·5%) was slightly lower than the CV for barley-urea concentrates (36·9 and 44·1 for groups A and B, respectively). This difference was difficult to interpret due to the difference in total amount of supplement DM allocated. Group A cattle received 25% more DM as barley-urea in Period 2 (equivalent to DE and DCP intake of block by group B cattle) than they consumed from the block during Period 1.

Group B cattle consumed 180% more DM/head from the block (Period 2) than was given in the barley-urea allocation (Period 1). The experiment might have been improved if the barley-urea concentrates had been

Table 45. Expt 12.2. Mean voluntary oat straw intake, live-weight gain and faecal chromic oxide concentrations

Supplementation	W291(74) feedblock		Barley-urea concentrate equivalent to DE and DCP intake of W291(74)		Barley-urea concentrate		Barley-urea concentrate equivalent to DM intake of W291(74)	
Group	A	B	A	B	A	B	A	B
Treatment period	(1)	(2)	(2)	(1)	(3)	(3)	(4)	(4)
Mean supplement intake kg DM/head	0.51±0.08	0.95±0.10	0.64	0.34	0.64	0.64	0.51	0.95
Mean daily live-weight gain kg/head	0.50	0.33	0.19	0.22	0.33	0.46	0.67	0.42
	0.44		0.21		0.40		0.55	
Voluntary oat straw intake kg DM/head/day	4.60	4.87	4.93	4.06	4.47	4.06	5.38	4.78
	4.74		4.50		4.27		5.08	
Mean and (Range) of faecal chromic oxide concentrations	43 (29-63)	62 (28-99)	145 (57-213)	68 (43-116)	102 (43-197)	99 (64-129)	115 (71-152)	182 (142-237)
CV %	29.6	38.5	36.9	44.1	52.6	22.5	27.5	21.0
	34.0		40.5		37.6		24.3	

allocated to the groups, according to their respective feedblock intakes rather than the 'pairfeeding' between the groups which occurred.

The importance of the quantity of DM allocated and the pattern of allocation, on individual variation in faecal chromic oxide concentration was illustrated in Period 4, when DM rather than DE and DCP intakes between the block and concentrates was equalised. The barley-urea concentrate was given at a constant daily allocation for both groups in Period 4, whilst the pattern of intake of both feedblock and concentrates in Periods 1 and 2 gave considerable inter-day fluctuations in total amount consumed. The CV for faecal chromic oxide were 27.5 and 21.0% (Mean 24.3) for groups A and B, respectively. The respective mean CV for feedblocks and concentrates given on a variable daily basis were 34.0 and 40.5%.

The CV for faecal chromic oxide concentration (52.6%) was 2.3 times greater, when an allocation of concentrates (0.64 kg DM/head) was given once daily, compared to when 2 daily meals each of 0.32 kg/head (22.5%) were given.

Discussion

Due to the design of the experiment and the small numbers of cattle available no statistical evaluations of the live-weight gain or straw intake data could be undertaken. Therefore the confidence which could be placed on these parameters was limited. There did not appear to be much difference in the voluntary straw intake when the cattle received equivalent DE and DCP from either feedblocks or barley-urea concentrates in a competitive situation.

The distribution of the feedblock and concentrate supplements between individual cattle in the groups was approximately similar, apart from when 0.64 kg/head of concentrates was given once daily (Period 3), when a high CV of 53% was recorded. There was no noticeable reluctance of individual cattle to compete for the material given. The main reason for this high CV was a high, faecal chromic oxide concentration for one individual animal. When this animal was removed from the analysis the CV was reduced to 35%. A high faecal chromic oxide concentration may reflect a high supplement or very low roughage intake, but the exact cause of the high value here was not known.

Although there was a considerable apparent advantage in terms of uniformity of supplementation when the same amount of concentrate DM was given in 2 daily feeds rather than once daily, little emphasis could be placed on the data. This was mainly due to the high CV for faecal chromic oxide when the concentrates were allocated once daily in Period 3, relative to the CV for concentrates given once daily in other periods, for example Period 4. A comparison between once and twice daily giving of concentrates using Periods 3 and 4 showed no difference in uniformity of supplementation.

When equal amounts of DM were allocated; concentrates given in troughs seemed to give a more uniform supplementation than blocks. When equivalent amounts of DE and DCP were given as concentrates and blocks (necessitating 0.67 kg concentrate DM to be given for every block consumed) the most uniform type of supplementation was slightly in favour of 'self-help' blocks. Further work of the consequences of variation in supplement intake on roughage utilisation in competitive situations is required.

Expt 12.3. A comparison between individually allocated concentrate and feedblock supplements given once or 10 times daily to beef cows

In Expt 12.1 a behaviour study of housed cattle given feedblocks showed that the number of visits to the block could be considerable (17 to 24 per 24-hr period). An average of over 60 minutes/day was spent at the block with the majority of activity occurring during the day-light hours (08.00 to 20.00 hr). The possible advantages of frequent urea intake on urea and roughage utilisation have already been discussed in the Introduction to this Section. However in Expts 12.1 and 12.2 no noticeable benefit of feedblocks consumed little and often, in terms of increased roughage intake, over an equivalent intake of DE and DCP given as concentrates once daily, could be detected. Any effect of frequency of urea intake seemed to be much less important than the individual variation in the absolute amount of supplement intake.

It was the intention of the present experiment to remove the variation in supplement intake, by individually allocating the feedblock and concentrate supplements given. Therefore any potential benefit of frequent urea intake from block material, resulting in increased roughage intake and/or digestibility, relative to giving similar nutrients once daily was more likely to be identified. Feedblocks of the W291(74) type were again used.

Materials and Methods

Twenty Hereford cross beef cows, mean live weight 484 kg were individually housed in stalls. The cows were 3 to 4 months pregnant at the onset of the trial. The experimental design used was five 4 x 4 Latin squares, each treatment being given in random sequence in 14-day Periods (56 days in total). The cows were allocated to each Latin square on the basis of live weight.

The following 4 dietary treatments were given to compare their effect on voluntary consumption and digestibility of oat straw.

A) An allocation of 840 g DM/head of W291(74) given as broken pieces (< 1 cm in length), once daily (08.00 hr). The block supplied about 60 g urea.

B) An allocation of 840 g DM/head as for A, but given in 10 feeds at constant intervals of 72 minutes between 08.00 and 20.00 hr.

C) An allocation of 570 g DM/head of a barley-urea cube supplying an equivalent amount of DE (8.7 MJ) and DCP (including 40 g urea) as A and B, given once daily.

D) An allocation of 530 g DM/head of a barley cube supplying an equivalent amount of DE as A, B and C, but no additional nitrogen.

The barley-urea and barley cubes also contained calcium, phosphorus trace element and vitamin inclusions. The chemical composition of the supplements used is given in Table 46.

The DE and DCP contents of the W291(74) block material were taken to be 10.4 MJ and 176 g/kg, respectively (Table 7). The DE and DCP of the barley used was as Expt 12.2, using the equation and values given in MAFF et al. (1975).

Throughout the experiment the cows were given ad libitum oat straw in long form, the intake of which was measured during days 8 to 14 of each treatment period. Samples of the oat straw were retained for chemical analysis (Table 46) every second day. Individual straw feeders were replenished when necessary. Any straw residues were collected daily and weighed; upon completion of each recording period a separate DM determination was carried out on a subsample of the straw residues from each individual cow.

Table 46. Expt 12.3. Mean composition of foods (g/kg DM)

	W291(74)	Barley-urea cube	Barley cube	Oat straw
CP	226.9	297.8	97.9	23.8
CF	28.0	41.5	42.6	447.6
EE	7.3	8.4	10.2	11.2
Ash	249.0	48.3	49.3	68.3
Ca	46.7	7.7	6.7	3.4
P	5.6	4.6	4.1	1.0

Additionally all the cows received 675 g DM/head/day of barley meal, containing 14.47 g chromic oxide/kg DM. Therefore the cows given the block received about 16.5 g chromic oxide/day, as the W291(74) material also contained 2.40 g chromic oxide/kg DM. Rectal grab samples were obtained 3 times daily during days 8 to 14 of each treatment period. These bulked faecal samples were analysed for chromic oxide, gross energy, organic matter and total nitrogen, using the methods described in the Introduction. The digestibility of the combined diets given was calculated using the chromic oxide faecal indicator technique.

At the end of Periods 1 and 2 all the cows were bled on 3 occasions (08.00, 11.00 and 16.00 hr) during the day. Additionally, in Period 2, the cows on each treatment were also bled at 14.00 and 20.00 hr to give a comparison of the blood parameters at the various sampling times during a 12 hour period (08.00 to 20.00 hr). In Period 1 both blood ammonia and plasma urea were measured whilst in Period 2 only plasma urea concentrations were measured. The cattle were reweighed upon completion of the experiment.

Results

In the initial period one individual cow refused to consume the W291(74) feedblock supplements and was replaced for all treatments with a comparable spare animal. Otherwise the block supplements were rapidly consumed, irrespective of pattern of feeding. Over the total 56 days of the experiment there was a mean live-weight increase of 8 kg.

The voluntary oat straw intakes and digestibility of the combined diets are presented in Table 47. There were no significant differences in voluntary intake, DM, OM, energy and nitrogen digestibility for treatments A, B and C, which supplied supplementary nitrogen. The voluntary intake of straw on these supplements was approximately 11% greater than for treatment D, when barley with no additional nitrogen was given. This increase in voluntary straw intake was significant ($P < 0.01$).

Similar highly significant differences in DM, OM, energy and nitrogen digestibilities were recorded for the treatments supplying supplementary nitrogen, compared with the barley alone supplement (Treatment D).

There was a slight but not significant tendency for the highest digestibility estimates to coincide with the giving of barley-urea concentrate (Treatment C). The nitrogen digestibility of the combined diet when barley alone was given was only just positive (0·14%), giving a mean apparent DCP digestion of 0·39 g. The determined (from nitrogen digestibility) amounts of DCP digested on the W291(74) block, given once daily or frequently and the barley-urea concentrate were 128, 142 and 115 g, respectively.

The mean plasma urea concentrations for Periods 1 and 2 are given in Table 48. At each sampling the lowest plasma urea concentrations were recorded for the barley alone treatment. The difference in plasma urea concentrations was significant at all samplings between barley-urea and barley and between W291(74) given once/day and barley at all

Table 47. Expt 12.3. Mean (20 cows) voluntary oat straw intakes and digestibility of the combined diet for the supplements given

	A	B	C	D		
Treatment	W291(74) 1x/day	W291(74) 10x/day	Barley-urea 1x/day	Barley 1x/day	SED+	Significance
Voluntary straw intake kg DM/head/day	7.31	7.34	7.39	6.56	0.25	A,B,C >D**
Digestibility % DM	55.5	55.8	56.3	50.6	1.53	C >D***; A,B >D**
OM	55.5	56.9	57.0	51.1	1.49	C,B >D***; A >C**
Energy	49.9	50.8	51.3	45.5	1.57	C >D***; A,B >D**
Nitrogen	29.5	32.6	28.1	0.14	3.49	A,B,C >D**
Total CP intake(Nx6.25)	433	434	408	277		
Apparent DCP digested	128	142	115	0.39		

+Standard error of the difference between two treatment means.

samplings except 08.00 hr. The mean plasma urea of the cows given W291(74) 10 x per day was consistently, but not significantly greater than those given barley alone, but of course, in the early part of the day those cows given W291(74) frequently had only received a small part of their total daily allocation. The changes in mean plasma for cows given either W291(74) or barley-urea concentrate once daily are essentially similar. The plasma urea flunctuations for cows given W291(74) frequently were not significant, but there was an increase between 08.00 hr, when block and the barley allocation was first given and 14.00, when about 50% of the days allocation of block had been given. The pattern of changes in plasma urea for the cows given W291(74) frequently resembled that of the barley-urea and W291(74) once daily treatments, but at lower absolute levels. There was little difference in mean plasma urea for any of the treatments between 16.00 and 20.00 hr.

The mean blood ammonia concentrations in Period 1 are also given in Table 48. There was considerable variation in this parameter for individual cows on the same treatment, reflected by the high standard errors of the mean. The mean blood ammonia concentration at 11.00 hr (69 and 64 μg/100 ml) was significantly ($P < 0.05$ and $P < 0.01$) higher than at 08.00 hr (37 and 35 μg/100 ml for cows given W291(74) once daily and barley-urea concentrate, respectively). There was little difference in blood ammonia at 08.00 and 16.00 hr for any of the treatments. The blood ammonia concentrations of the cows given W291(74) frequently, resembled very closely, at all samplings, those of the cows receiving barley alone with no additional nitrogen.

Discussion

In this experiment no additional response to frequent intake of NPN was measured, in terms of increased voluntary intake and/or digestibility, over and above that of offering the same amount of DCP in the block or barley/urea concentrate once daily. Supplementary

Table 48. Expt 12.3. Mean (± SE) plasma urea (mg/100ml) and ammonia (μg/100 ml) concentrations

	A	B	C	D	
Treatment	W291(74) 1x/day	W291(74) 10x/day	Barley-urea 1x/day	Barley 1x/day	Significance
Urea					
Time (hr)					
08.00	12.78±1.38 [+]	10.28±1.76	14.16±1.69	8.20±1.65	C > D**
11.00	18.28±1.97 [+]	12.75±2.03	17.24±1.92	10.06±1.00	C, A > D**
14.00	25.50±2.27 [++]	17.52±3.30	24.24±3.06	10.84±1.51	C, A > D**
16.00	15.14±1.89 [+]	10.14±1.66	14.56±1.69	6.46±0.29	C > D*** A > D**
20.00	16.54±1.87 [++]	13.12±3.23	16.28±2.56	8.68±1.86	A, C > D*
Ammonia					
08.00	37±3.0 [++]	39±2.6	35±4.6	42±2.8	NS
11.00	69±8.4	47±4.8	64±3.6	53±5.0	NS
16.00	40±4.5	41±6.7	44±7.6	43±3.5	NS

[+] Mean of 10 cows for each of the 4 groups.

[++] Mean of 5 cows for each of the 4 groups.

nitrogen as either feedblock or barley-urea concentrate, increased the voluntary intake of oat straw by about 11%, with a correspondingly increased digestibility of about 6 percentage units. In an experiment with similar cows, Fishwick, Fraser, Hemingway, Parkins and Ritchie (1974) reported an increase in oat straw consumption of 20% with nitrogen supplementation, which increased the total ME intake from about 54 to 63 MJ/day. The mean ME intake from the barley alone (no additional nitrogen supplementation) treatment was about 60 MJ ME in the present study. The ME requirement (MAFF et al. 1975) for cows in the initial 5 months of pregnancy does not exceed that of non-pregnant cows by more than 5 MJ. The ME requirement for maintenance of cows of mean live weight 484 kg is 52 MJ. The range in live weights between the cows was 386 to 606 kg with a corresponding range in ME requirements of 43 to 64 MJ. Therefore all the cows consumed adequate energy, irrespective of whether additional nitrogen was given in the supplements.

The improvement in straw intake with additional nitrogen, resulted in an increased ME intake in the total diet of 5 to 6 MJ. The mean CP content of the total diet consumed by the cows given barley alone supplements, was estimated to be 35·6 g/kg. Nitrogen supplementation increased this to about 50 g CP/kg and apparent DCP of the diet by a factor of at least 3. The apparent DCP from the diet (calculated from the nitrogen digestibility data) with the barley alone supplementation was 0·39 g, compared with about 128, 142 and 115 g DCP, when the block once daily, block frequently and barley urea supplements, respectively were given. These apparent amounts of DCP digested were far lower than the intended intakes of DCP from the supplements given. Each supplement containing additional nitrogen should have offered about 148 g DCP, giving a total DCP intake discounting the oat straw of about 200 g DCP (55 g DCP were contained in the 0.68 kg DM/head allocation of barley). The nitrogen contained in the W291(74) feedblock given frequently, seemed to marginally allow the highest digestibility of crude protein. For the barley alone treatment, the DCP intake discounting the straw should have been about 100 g. Therefore either nitrogen digestibility underestimates the apparent DCP digested, or the calculated DCP intakes from the amounts assumed to be in the foods given, were overestimated.

The report of Fishwick et al. (1974) makes no reference to the nitrogen digestibility of the predominantly oat straw diets given. There appear to be at least two possible explanations for the difference between amount of DCP given and that apparently digested. Firstly, there may be an error resulting from the chromic oxide faecal indicator technique, although this seems very unlikely to account for all the difference and might have been constant for all treatments. Secondly, the discrepancy may be due to the endogenous output of metabolic faecal nitrogen (MFN). According to the ARC (1965) the magnitude of MFN excretion in both cattle and sheep is about 5 g MFN/kg of DM intake. The cows given barley alone with no additional nitrogen consumed an average 7·77 kg DM/head/day, which would result in 39 g MFN or 243 g crude protein from endogenous sources. The total crude protein intake of these cows was an average 277 g (including a calculated 100 g DCP), of which only 0·39 g CP were apparently digested using the nitrogen digestibility data. The apparent digestibility of the dietary crude protein was virtually zero. Of the 277 g CP excreted in the faeces, 243 could be attributed to the endogenous secretion of MFN from a diet of about 7·8 kg DM. Therefore the true digestibility of crude protein of the combined diet was $\frac{277 - 34}{277}$ x 100 which equals 88%. This seems rather high although some of the MFN might be accounted for, as dietary nitrogen recycled via the saliva.

Similarly for the nitrogen supplemented cows the MFN outputs were calculated to be 43, 44 and 44 g N (269, 275, 275 g CP) for the cows given barley-urea, W291(74) once daily and W291(74) frequently, respectively.

The total crude protein intakes were 408, 433 and 434 g/head/day, respectively and amounts of DCP (calculated from the N digestibility) apparently digested were 115, 128 and 142 g. The total amount of crude protein excreted in the faeces was then 293, 305 and 292 g. Again most of the crude protein excreted was attributable to the calculated endogenous secretion of crude protein into the digestive tract. (92, 90 and 94% for the barley-urea, block once daily and block frequently, respectively). This implies a high efficiency of true digestion of crude protein in the combined diets of 94, 93 and 96%, respectively, for the barley-urea, block once daily and block frequently treatments. Although this assumption may have again been complicated by the recycling of nitrogen via the saliva.

This experiment illustrates an inconsistency between the calculated DCP intakes of cows on predominantly straw diets and the in vivo measurement of the amount of CP apparently digested. The DCP recommended requirements (ARC 1965) for maintenance of mature cows weighing 500 kg live weight and consuming 9 kg DM/head/day are 236 g/day. Using the DCP value for oat straw of 11 g DCP/kg (MAFF et al. 1975) and assuming that urea is totally digestible, the cows in the present experiment should have received ample DCP (280 g/head) on the additional nitrogen treatments (19% in excess of maintenance) and 180 g/head on the barley alone supplement. The amounts of DCP apparently digested using the in vivo determined nitrogen digestibilities for the combined diets were only 49, 54 and 60% of the DCP recommendations for the barley-urea, block once daily and block frequently treatments, respectively. Therefore on these treatments only about 43 to 50% of the calculated DCP given was identified as being apparently digested in vivo. On the barley alone/no additional nitrogen treatment, none of the calculated (180 g) DCP given was identified as being apparently digested in vivo, using the nitrogen digestibility estimate (0.14%). Even after 84 days on these diets no impairment of health or digestive function was noticed, therefore in practice the cows must have received sufficient protein in their diets on average.

There appears to be a confusion under certain circumstances of the terms 'calculated DCP intake' and that part of the crude protein in the diet which is apparently digested. The latter concept is also termed DCP, but as shown in the present experiment there is a considerable discrepancy between the two in practice. The main reason for this discrepancy, especially on predominantly straw diets is the endogenous secretion of MFN. Again, both in vivo DCP apparently digested (from the percentage nitrogen digestibility of the diet) and the calculated intake of DCP (using the criterion that urea is 100% digestible) should, by definition fully take into account MFN. Metabolic faecal nitrogen and hence calculated DCP intake is dependent on DM intake, therefore the DCP intake on any diet must be qualified in relation to the total DM intake, as indicated by the (ARC 1965) and perhaps even the quality of the roughage. The recommended requirements for protein are tabulated as available protein (AP) which is converted to DCP by adding, 13·4 x DM intake kg/day. Assuming no interaction between the dietary components, the more straw that is consumed the greater will be the MFN output and the discrepancy between calculated DCP intake and that apparently digested, should expand accordingly.

There may be a peculiarity of very low nitrogen, for example predominantly straw diets to show, irrespectively of DM intake a greater discrepancy between calculated DCP intake and that apparently digested, than for other diets, for example when good hay is the predominant roughage. This phenomenum requires further examination.

Although there were no noticeable advantages of giving urea in a feedblock frequently relative to once/day, in terms of roughage utilisation, it is possible that in other circumstances (e.g. energy deficit) frequent administration of urea might be important. Any response to NPN supplementation,compared to the intake and digestibility of roughage alone,is always likely to be considerably greater than any additional response concerned with the pattern of giving the NPN. In the present experiment a small but significant difference between NPN-supplementation and no NPN-supplementation of 11% was detected. Whilst sensitive enough to identify gross differences in the qualitative nutrition of the cows the present experiment was never likely to identify a possible more subtle response,dependent on how the difference in qualitative nutrition was effected. A possible advantage of 'self-help' systems of giving supplementary NPN compared with 'hand-feeding' requires further investigation, particularly under circumstances where as energy deficit exists, as is commonly the case with breeding cows and ewes kept under hill conditions. However the magnitude of any possible advantage in terms of improved roughage utilisation due to frequency of NPN intake,is always likely to be below any response resulting from NPN supplementation compared to no supplementation.

B The effect of feedblock ingredients, including EC feed on the utilisation of roughages

The most extensively used feedblock-type at present in the United Kingdom is marketed under the proprietary name, Rumevite. The shape, method of manufacture, and intended role of Rumevite feedblocks in animal production systems has clearly been described in the Introduction to this thesis. The principal aim of Rumevite feedblocks is claimed to be the enhancement of roughage utilisation. Several different Rumevite feedblock formulations apparently exist which probably differ only minimally in chemical composition. Throughout this thesis two of these Rumevite blocks (RS and RHE) have been studied in detail, the typical chemical composition of these blocks is given in Table 1. The formulation of the RS feedblock according to Sarif-Sarban and Menke (1970) is 500 g maize, 150 g salt, 60 g urea, 30 g mineral mixture and 260 g EC feed (distillers molasses dried solubles)/kg DM. The possible effects of urea and supplementary carbohydrate on roughage utilisation have already been reviewed in this Section and it appears conclusively that supplementary nitrogen and/or carbohydrate can improve utilisation under certain circumstances. This is usually reflected in an increased voluntary roughage intake and/or digestibility.

The mineral inclusion in RS feedblocks could improve roughage utilisation by alleviating a specific dietary deficiency of a mineral, for example phosphorus. However Rumevite feedblocks are exceptionally low in phosphorus (2·8 and 3·8 g P/kg for the RS and RHE blocks respectively), relative to other feedblocks and barley (about 4·0 g P/kg). This low phosphorus inclusion rate combined with the low feedblock intake intended makes their suitability as phosphorus supplements highly debatable.

Unlike most concentrate foods, the majority of feedblocks (including Rumevite) contain appreciable inclusions of sodium chloride (salt), to aid in intake control. The suitability of salt as an appetite regulator has been reviewed in the Introduction to this thesis. High salt intakes can be detrimental to animals, particularly if food or water supplies are restricted. This may take the form of a physiological dysfunction (Bolin, 1949) or an impairment of digestive function (Moseley and Jones, 1974).

The physiological consequences of a high salt intake have already been reviewed. The effect of high salt intakes on digestive efficiency has been the subject of several studies, the results of which tend to be complicating. Riggs et al. (1953) were the only workers to report an increase in digestibility with high salt rations. The digestibility of all nutrients, particularly crude protein, crude fibre and nitrogen free extract appeared to be increased, but only two animals were used per treatment. Meyer et al. (1955) studied the digestibility and nitrogen balance of growing and fattening sheep given rations with up to 128 g salt/kg. No significant effect was measured in nitrogen digestibility, nitrogen retention or TDN of the basal ration. Also, no detrimental effect was produced on daily live-weight gain or food conversion efficiency. The high salt intakes had no effect on the number of stomach worms present.

The above work is largely in agreement with that of Nelson et al. (1955) who reported that steers and wethers given normal and high salt rations did not significantly differ in their ability to digest organic matter and nitrogen free extract. However, there was a slight (but non significant) decrease in nitrogen retention for both species.

Recently, Moseley and Jones (1974) have reported a detrimental effect of salt when growing wethers were given diets increasing in salt content from 26 to 74 g/kg. Dry matter intake, organic matter intake and organic matter digestibility were significantly reduced at the highest salt intake. There was also a reduction in live-weight gain and efficiency of utilisation of digestible organic matter with increasing salt supplementation. Serum calcium and magnesium concentrations were significantly lowered as a result of salt supplementation. Salt improved the apparent availability of sodium, potassium, magnesium and calcium but reduced that of phosphorus and nitrogen.

The effect of sodium and potassium chloride in diets in the energy metabolism of sheep has been studied by Kromann and Ray (1967) and by Jackson, Kromann and Ray (1971). The sodium chloride levels given (18, 33, 48, 58 and 76 g/kg DM), linearly decreased weight and energy gain, empty body weight and energy and percentage carcass fat. Potassium (7 to 30 g/kg DM) also linearly decreased energy and weight gain, but did not significantly influence the other criteria. High levels of sodium (30 g Na/kg DM) were more detrimental to growth and energy retention than the higher levels of potassium (30 g K/kg DM), since sodium was detrimental in all the criteria and potassium was only detrimental to energy and weight gain.

The published data on the effect of high dietary salt intakes on the performance and health of ruminants suggests that there are undoubtedly circumstances where a high salt intake may cause detriment. It was one of the objectives of the following experiment to examine the effect of the salt inclusion in a feedblock (Rumevite) on roughage utilisation.

It is claimed by the manufacturers of Rumevite feed blocks that the ingredient EC feed will improve roughage utilisation by amounts up to 50% (e.g. Scottish Farmer, Nov 17, 1973). There is no published communication to verify this claim. On the contrary, in the only scientific report where EC feed has been examined, Unsworth et al. (1966), revealed a detrimental effect of EC feed on hay digestibility. In view of the emphasis placed on the claimed ability of EC feed to enhance roughage utilisation by the manufacturers and the contradictory nature of the work of Unsworth et al. (1966), two experiments were carried out to evaluate the ingredients of Rumevite feedblocks, particularly EC feed, with respect to roughage utilisation.

Expt 13.1 The effect of the major ingredients of Rumevite feedblocks given individually and in combination on the digestibility of roughages

Materials and Methods

Thirty adult (Border Leicester x Cheviot and Border Leicester x Scottish Blackface) wethers, weighing 46 to 80 kg, were allocated to six equal groups according to breed and live weight. Each group of sheep was arranged in a 5 x 5 Latin square design and the animals confined in metabolism chages. Two Latin squares (10 wethers) were given a fixed allocation (approximately 520 g DM) of one of the following chopped roughages, barley straw, timothy hay (full seed) or meadow hay (good quality). The roughages used were chosen on the basis of their crude protein and crude fibre contents (Table 49), such that a gradation in quality occurred from straw to good hay. Digestibility estimates of these roughages alone were obtained after completion of two treatment periods of the Latin square.

The constant quantity of roughage given each day to each sheep was determined by the amount of barley straw consumed on average. Thus it was hoped that differences in the level of roughage consumption which might otherwise affect digestibility would be eliminated. The roughage allocations were given in two approximately equal daily feeds (08.00 and 16.00 hr). Residues (straw treatments only) were collected prior to each morning feed and samples retained for DM determination.

Table 49. Expt 13.1. Mean Composition of foods (g/kg DM)

	Barley straw	Timothy hay	Meadow hay	Barley	EC feed
CP	31.6	54.2	81.1	91.4	91.7
CF	444.7	304.6	294.5	39.3	0.6
EE	12.8	16.7	15.7	18.0	1.1
NFE	461.3	577.9	551.1	830.3	565.5
Ash	49.6	46.6	57.6	21.0	341.1
Calcium	3.70	3.96	5.07	0.79	5.90
Phosphorus	0.76	3.42	2.40	3.87	2.50
Sodium	0.52	0.49	0.62	0.09	4.3
Potassium	11.22	9.73	18.09	3.79	79.66

Additionally the following five supplements based on the formulation of Rumevite given by Sarif-Sarban and Menke (1970) were offered at two levels equivalent to 60 or 120 g DM of Rumevite.

At the 60 g DM level

A) 30 g barley + 1·8 g mineral mixture (31·8 g DM)

B) 30 g barley + 1·8 g mineral mixture + 3·6 g urea (35·4 g DM)

C) 30 g barley + 1·8 g mineral mixture + 15·6 g EC feed (47·4 g DM)

D) 30 g barley + 1·8 g mineral mixture + 9·0 g salt (40·8 g DM)

E) 30 g barley + 1·8 g mineral mixture + 3·6 g urea + 15·6 g EC feed + 9·0 g salt (60 g DM).

At the 120 g DM level the amounts given were exactly doubled. For each of the three roughages, a low and high level of Rumevite supplementation was given. The amounts offered were chosen on the basis of data collected from outwintered ewes, where the voluntary intakes of RS feedblocks varied between about 60 to 120 g DM/head/day. Thus the Rumevite ingredients were evaluated at two levels of supplementation. The formulation of Rumevite quoted by Sarif-Sarban and Menke

(1970) assumes 500 g maize/kg as the cereal component; in the present experiment the maize was substituted on a DM basis with barley (Table 49 for chemical composition). The mineral mixture used here was composed of dicalcium phosphate, calcium carbonate and a proprietary trace element/ vitamin mix in the ratio of 2 : 2 : 1, as the exact composition of the mineral mixture used in Rumevite was not disclosed.

The simulated Rumevite supplements were given in a loose mix once daily (10.00 hr), with the minor inclusions of mineral, urea and salt dispersed thoughout the barley and EC feed. On occasions EC feed was initially rejected, but after mixing with the roughage this was consumed. Water was available at all times.

The wethers were equipped for quantitative faecal collections with harnesses and rubberised canvas bags for intervals of 7 days, following 7 days of introduction to each treatment. Faeces were sampled according to Method 1 in the Introduction (Page 71). Composite faecal samples were subsequently analysed for DM, ash, energy and nitrogen using the techniques described in the Introduction.

The sheep were reweighed upon completion of the experiment.

Results

In the calculation of roughage alone digestibility when the supplements were given, urea was assumed to be fully digestible. The DM and OM digestibilities of the barley used were assumed to be 80 and 86%, respectively. The DE of the barley was assumed to be 16·7 MJ/kg. The digestibility of nitrogen in the barley was taken to be 76%. These estimates were derived from the standards outlined by MAFF et al. (1975). For example, a crude protein in barley of 108 g/kg results in a DCP of 82 g/kg or a nitrogen digestibility of 76%. No digestibility estimates for EC feed could be discovered, therefore the results make no allowance for faecal constituents derived from this ingredient. The ME of EC feed was calculated to be 9·1 MJ/kg (MEF = 0.012 CP + 0.031 EE +

0.005 CF + 0.14 NFE, MAFF et al. 1975) and DE 11.2 MJ/kg ($DE = \frac{ME}{0.81}$, MAFF et al. 1975). The gross energy of EC feed was measured as 12.9 MJ/kg therefore the energy digestibility of EC feed was reasonably assumed to be 87%.

One wether on the straw roughage plus treatment D (barley, mineral, salt) at the 120 g level of supplementation, lost appetite. This returned when the succeeding treatment was offered. A repeat of this treatment was carried out with a comparable spare animal. A second wether on the straw roughage plus treatment A (barley, mineral alone) developed symptoms of cerebro cortico necrosis, which responded to treatment with a course of thiamine hydrochloride injections; the appetite of the animal was immediately restored.

All sheep lost weight during the 84 days of the experiment varying from about 5 to 27% of their initial live weight. Details of the live-weight changes are given in Table 50. The wethers given good quality meadow hay lost significantly ($P < 0.05$) less live weight (13.3%), on average than those given straw (19.4%). The wethers given the stemmy timothy hay had a mean weight loss (16.0%) intermediate between those of the barley straw and meadow hay roughage treatments, but the differences were not significant. There was no significant influence of the level of Rumevite supplementation (60 or 120 g DM) on the magnitude of the live-weight losses.

The effect of the Rumevite constituents on roughage digestibility is given in Table 51. The quality of the roughage given rather than type of supplementation was the principal determinant of digestibility. The mean DM digestibilities of the barley straw, timothy hay and meadow hay given without supplementation were 45.9, 54.8 and 66.6%, respectively. The effect of level of Rumevite supplementation on roughage digestibility was not significant. There was a trend at the 120 g level of

Table 50. Expt 13.1. Mean live-weight changes (kg)

Roughage	Barley straw		Timothy hay		Meadow hay	
Rumevite supplementation (g DM) live weight (kg)	60	120	60	120	60	120
Inital	59.6	60.0	59.9	58.2	58.0	59.8
Final	47.1	49.4	50.8	48.5	49.7	52.5
Loss	12.5	10.6	9.1	9.7	8.3	7.3
% Loss	21.0	17.7	15.2	16.7	14.3	12.2
	19.4		16.0		13.3	

Significance

Barley straw > Meadow hay* SED between 2 means = 1.97

supplementation for the treatments containing EC feed (D and E) to have lower digestibility estimates than at the 60 g level. In general however, the effect of the individual supplements tended to be small and highly variable,irrespective of level of supplementation.

Barley plus mineral alone or with salt had no significant effect on any of the roughages. Urea did not significantly increase the roughage digestibility and at the 120 g level,given to the sheep on meadow hay,significantly ($P<0.05$) decreased DM and OM digestibility. The corresponding treatments containing EC feed,either with or without urea (treatments C and E) also significantly decreased the DM, OM and nitrogen digestibility of the meadow hay. The energy digestibility was lowered on these treatments,but to a level just short of statistical significance.

Table 51. Expt 13.1. Digestibility estimates (%) of roughages supplemented with Rumevite ingredients at 2 levels

Treatment++	A Barley, mineral		B Barley, mineral + urea		C Barley, mineral + EC feed		D Barley, mineral + salt		E Barley, mineral + urea + salt + EC feed		Roughage alone (10 sheep)
Supplement (g DM))	60	120	60	120	60	120	60	120	60	120	
Roughage											
Barley straw											
DM	47.2	44.8	46.7	47.3	47.7	43.7	47.6	46.5	47.4	44.0	45.9
OM	48.4	45.9	47.7	48.3	49.1	45.4	48.8	47.0	48.5	46.1	46.9
Energy	45.6	45.9	45.8	47.6	47.4	44.2	47.0	47.8	46.7	44.7	44.7
Nitrogen	-30.0	-32.7	-34.6	-34.6	-25.7	-30.1	-28.5	-22.7	-45.2	-62.8	-38.9
Timothy hay											
DM	55.7	54.6	56.8	55.7	55.8	52.7	53.8	56.4	54.4	53.7	54.8
OM	57.1	57.2	57.9	56.9	56.9	54.9	54.9	57.3	55.8	55.8	56.2
Energy	55.7	56.2	56.6	55.4	56.1	53.5	54.9	55.6	55.7	56.9	55.4
Nitrogen	37.9	33.7	38.2	33.2	30.3	22.6*	25.1	32.1	29.9	23.1*	25.5
									SED+ = 3.95		
Meadow hay											
DM	67.0	67.1	67.0	65.7*	66.5	63.4**	68.1	67.4	67.4	65.2**	66.6
									SED+ = 0.46		
OM	68.1	68.2	68.1	66.7	67.6	65.3	69.0	68.3	68.7	66.6	67.6
									SED = 0.46		
Energy	67.2	67.7	67.3	66.7	66.5	64.2	68.8	67.4	68.1	67.4	66.9
Nitrogen	51.8	52.8	53.6	53.8	55.2	44.0**	54.8	54.2	52.9	47.1*	48.1
									SED = 2.56		

+ Standard error of the difference between two treatment means given only for significant effects

++ Mean of 5 sheep at each level.

At the 120 g supplementation level the treatments containing EC feed (C and E) gave significantly ($P < 0.05$) lower nitrogen digestibilities (22.6 and 23.1%, respectively) for the timothy hay, compared with the other supplementation treatments (33.7, 33.2 and 32.1% for the barley-mineral alone, barley-mineral plus urea and barley-mineral plus salt treatments, respectively).

All other treatment comparisons were statistically not significant. The ME contents of the three roughages used as determined from the DE values were 9.95 ± 0.13, 8.75 ± 0.12 and 10.99 ± 0.17 MJ/kg for the barley straw, timothy hay and meadow hay, respectively. The DCP contents were 12.3 ± 0.17, 13.7 ± 0.21 and 39.0 ± 0.58 g/kg for the barley straw, timothy and meadow hay, respectively.

Discussion

The plane of nutrition existing in this experiment was intentionally sub-maintenance. It was considered that this would approximate more closely to the winter situation, where hill ewes are often supplemented with low intake feedblocks, under circumstances where net live-weight loss could potentially be considerable. The ME requirement for maintenance of 60 kg sheep (MAFF et al. 1975) is 6.8 MJ. In the present experiment the sheep given 0.52 kg of DM barley straw (ME = 6.95 KJ/kg) received a total of 4.2 and 4.7 MJ for the 60 and 120 g levels of supplementation, respectively (the barley supplied 0.41 and 0.82 MJ and the EC feed supplied an estimated 0.14 and 0.28 MJ ME at the 60 and 120 g levels, respectively). Therefore they received 62 to 69% of their mean ME requirements for maintenance.

The sheep given 0.52 kg timothy hay (ME = 8.75 KJ/kg) received a total of 5.1 and 5.7 MJ ME at the 60 and 120 g DM levels of supplementation, respectively. This amounted to between 75 and 84% of their mean ME requirements for maintenance. The sheep given 0.52 kg DM of meadow hay (ME = 10.99 MJ) received 6.3 and 6.8 MJ ME at the 60 and 120 g levels of supplementation. This amounted to 93 and 100% of maintenance. These levels of energy nutrition applied to all treatments when both barley and EC feed were given, the other treatments A, B and D would supply slightly less energy. The live-weight losses, particularly on the meadow hay treatments, were above what might have been expected from the amounts of ME given. However this weight loss includes a 14-day period when the sheep received no supplementation and consequently less energy (10 to 20%) in total.

In addition to the sub-maintenance plane of nutrition for energy, the sheep were in most instances receiving less than their minimum requirements for protein. According to the ARC (1965) estimates, crossbred sheep weighing 60 kg, required 37 and 38 g DCP at the 60 and 120 levels of supplementation, respectively. When given either alone or with supplementation the nitrogen digestibility (and hence DCP apparently digested) of the barley straw was negative. The reason for this was outlined in Expt 12.3. Therefore in the computation of a DCP intake for the sheep on the predominantly barley straw treatments, a value of 9 g DCP/kg for the straw was assumed (MAFF et al. 1975). The CP in EC feed was ignored; urea was assumed to be fully digestible and the CP in the barley was taken to be 76% digestible. The maximum calculated DCP intakes on the supplemented barley straw treatments were then 17.2 and 29.8 g at the 60 and 120 g levels of supplementation, respectively, or 47 and 78% of the DCP maintenance requirement. On treatments supplying no urea much less DCP would be available. The treatments supplying additional nitrogen as urea (B and E) increased the CP of the diet from 3.6 to 5.4 and 4.1 to 7.2% at the 60 and 100 g levels of supplementation, respectively.

In the computation of the DCP intakes by the sheep on the timothy hay diets, there was no tabulated value of DCP for a hay with a CP as low as 54.2 g/kg. The in vivo apparent digestion of the CP in this hay, when given alone to sheep was 25.3%, giving a DCP content of 13.7 g/kg. This value may be unsuitable in a calculation when comparison with the ARC (1965) requirements is made, because of the discrepancy between calculated DCP intake and DCP apparently digested for poor quality roughage diets. Nevertheless, 13.7 g DCP/kg was the only estimate available for use. The DCP intakes were then a maximum of 19.7 and 32.2 g/head/day on the treatments supplying urea, at the 60 and 120 g levels of supplementation, respectively, or 53 and 85% of the recommended intakes for maintenance.

The DCP content of hay of CP content 85 g/kg is given as 39 g/kg (MAFF et al. 1975). The meadow hay used in the present experiment had a CP of 81.1 g/kg and an in vivo apparent digestion of this CP when given alone of 37 g/kg. Therefore there was very close agreement with the good hay treatments, between the calculated DCP intake and that apparently digested. The DCP intakes on the meadow hay treatment, when urea supplementation was given were 31.7 and 44.3 g or 86 and 117% of the amounts required for maintenance, at the 60 and 120 g levels of supplementation, respectively. Although qualitatively never deficient in CP (the meadow hay per se contained 81.1 g CP/kg), when the meadow hay was given at the lower (60 g) level of supplementation a quantitative deficiency of DCP (albeit small) was found. Therefore although it has been claimed (Eadie, quoted by Armstrong and Trinder 1966) that the diet selected by the hill ewe is never less than 87 g CP/kg in qualitative terms, which largely precludes a significant response to nitrogen supplementation, there may be situations in practice where additional DCP is required due to the very low DM intakes. In the present experiment the barley in the supplements gave 2.4 to 4.9 g additional DCP.

Despite the sub-maintenance plane of protein nutrition, the most likely explanation of the failure of any of the ingredients given in Rumevite to show a positive effect on roughage digestibility, was due to the substantial energy deficit on all treatments. However, a specific deficiency of a mineral, e.g. phosphorus, cannot be ruled out, particularly on the barley straw roughage treatments. The manifestation of any resulting, impaired digestive function would probably have been gradual with differences in mean digestibility between periods. These did not occur. The phosphorus intakes of the sheep given barley straw were 12.0 and 16.0 mg/kg live weight, those given timothy hay were 35 and 38 mg/kg live weight and those given meadow hay 26 and 30 mg/kg live weight, at the 60 and 120 g levels of supplementation, respectively. These are the phosphorus intakes on treatments when supplementation was given. When roughage only was given phosphorus intake would be even lower. The mineral inclusion in the supplements given supplied 0.13 and 0.25 g P/head/day at the 60 (1.8 g mineral) and 120 g (3.6 mineral) levels, respectively (the mineral mixture contained 400 g dicalcium phosphate with 175 g P/kg). The ARC (1965) requirements of phosphorus for sheep does not tabulate amounts required for maintenance. Sheep weighing 60 kg and growing at 50 g/day require 80 mg P/kg. Therefore it would be reasonable to assume that the wethers given barley straw at least were in a situation where a phosphorus deficiency might have impaired digestive function.

Therefore a second possible explanation for the absence of any response to supplementary nitrogen, particularly on the barley straw treatments may have been due to the 'masking' effect of a phosphorus deficiency. Nevertheless the amount of phosphorus given in the mineral mixture and the supplements in general (3.8 g P/kg in treatment E, equivalent to Rumevite) was in fact greater than usually measured in RS feedblocks (2.8 g P/kg, Table 1). Therefore if a phosphorus deficiency was important, it reflected unfavourably against this particular block, which appears to be a very low source of phosphorus.

The only significant effect of the treatments given, was a negative effect of those containing EC feed, C and E, on the nitrogen digestibility of both the hays and also the DM and OM (E only) of the meadow hay. Supplementary urea given in treatment B also surprisingly gave a significant reduction in the DM digestibility of the meadow hay compared with treatments A and D. The supplement D providing the salt inclusion of Rumevite feedblocks did not per se, appear to be detrimental to any of the digestibility fractions examined, even at the higher level.

The significantly lower DM digestibility of the meadow hay with urea, compared to the barley alone A, and barley plus salt D treatments may be an artifract, otherwise an explanation for this occurrence is difficult to obtain. The lowered digestibility with some diets containing EC feed is in agreement with Unsworth et al. (1966). The reason for this negative effect on digestibility is at present unknown. EC feed is high in potassium (80 g K/kg) which has been shown (Jackson, Kromann and Ray 1971) to adversely affect energy and live-weight gain of growing lambs at between 7 and 30 g K/kg diet. Sodium at similar levels in the diet produced an equivalent result. Increasing levels of sodium in the diet (17 to 31 g Na/kg) as given by Moseley and Jones (1974) also adversely affected voluntary intake and OM digestibility. Therefore it is possible that the sodium and potassium concentrations in the diet, or the concentration of both cations combined might have been sufficient, when EC was additionally given to lower digestibility. The meadow hay, of the roughages given had the highest content of both potassium (1.8 g/kg) and sodium (0.62 g/kg) and it was with this roughage that the negative effect of supplements containing EC feed was most pronounced.

The concentrations of sodium in the diet when treatments containing salt plus EC feed were given (treatment E) were 11.5, 11.5 and 11.8 g

Na/kg for the barley straw, timothy hay and meadow hay, respectively, at the 120 g level of supplementation. The concentrations of potassium in the diet when treatments (120 g level) containing EC were given (C and E) were 13.3, 12.1 and 18.8 g K/kg for the barley straw, timothy hay and meadow hay, respectively. The concentration of sodium, per se, in the diets does not appear to be sufficient to be detrimental. The concentration of potassium in the diet, particularly with the meadow hay roughage (which already has a high potassium content 18.1 g/kg) is within the range shown by Jackson, Kromann and Ray (1971) to be detrimental to energy and live-weight gain. The combined concentration of both sodium and potassium cations (about 25, 24 and 31 g/kg for the barley straw, timothy hay and meadow hay, respectively) may be more important than the individual concentrations. The presence of a sub-maintenance level of nutrition may have exacerbated any detrimental effect of sodium and/or potassium in the diet. Further work is required on the effect of EC on roughage utilisation especially in a situation where roughage intake is given ad libitum and voluntary consumption is also measured. This was the purpose of Expt 13.2.

Expt 13.2. The effect of the major ingredients of Rumevite feedblocks on the voluntary consumption and digestibility of roughages

In Expt 13.1 there was a complete failure of any of the Rumevite ingredients to effect a positive response on the digestibility of roughages. There was a tendency for the treatments containing EC feed to show the lowest digestibility for the proximate fractions studied, particularly with the highest quality hay. The overall plane of nutrition given in that experiment, irrespective of roughage quality was sub-maintenance. This was always the case for energy, virtually always for protein and also for phosphorus, especially on the barley straw roughage.

In many hill and other situations where supplement-type feedblocks are given, the diet available may be both quantitatively and qualitatively deficient as was intended for Expt 13.1. In other situations roughage is available in ad libitum quantities but may be often qualitatively deficient in certain nutrients such as nitrogen and/or phosphorus. In Expt 13.2 ad libitum roughage was provided differing in quality and the effect of the ingredients of Rumevite feedblocks on roughage utilisation was measured as before, but now incorporating an estimate of voluntary roughage consumption. The levels of Rumevite supplementation were also slightly increased to the ingredients present in either 70 or 140 g DM.

Due to the limitation on experimental resources the effect of the salt inclusion in Rumevite feedblocks was not evaluated separately and additional salt was given in all the treatments. In Expt 13.1 the amounts of supplementary nutrients given, as determined by their inclusion in the block and the estimated intake range (in a practical situation), were perhaps insufficient to fundamentally improve the nutritional status of the sheep. Therefore in the present experiment an additional treatment, unconnected with the formulation of RS feedblocks was included, where a larger amount of nutrients was given. This was intended to approximate to a nutrient intake level commensurate with 'hand-feeding', for example cobs, or concentrates, or even to the intake from a higher intake, substitute-type feedblock.

Materials and Methods

Apart from the modifications already described, the present experiment was essentially similar in design and procedure to Expt 13.1. Thirty adult (Border Leicester x Cheviot and Border Leicester x Scottish Blackface) wethers weighing 39 to 77 kg (Mean live weight 58 kg) were allocated to six equal groups according to breed and live weight. Each group of sheep was arranged in a 5 x 5 Latin square design and the animals confined in metabolism cages. Two Latin squares (10 wethers), received barley straw, a further two squares were given hay I and the remaining two squares received hay II. As before the roughages used were intended to provide a gradation in quality from straw to good hay. In practice the difference between the two hays was minimal. All the roughages were given in a shredded form, with a chop-length of 1 to 5 cms. Digestibility and voluntary intake estimates of the roughages were obtained in an additional 17-day period, upon completion of the periods of each Latin square. The measurement of ad libitum consumption of the roughage entailed replenishing the individual hay feeders at least four times daily. It was the intention that there should always be material left unconsumed by next morning, which was then removed and a separate DM determination carried out on the 7-day accumulation of residues. The composition of the foods given is outlined in Table 52.

Additionally, the following five treatments were offered, the first four of which were based on the formulation of Rumevite as given by Sarif-Sarban and Menke (1970). Those supplements based on Rumevite were again offered at two levels (70 and 140 g DM) of supplementation.

At the 70 g DM level

A) 35 g barley + 2.1 g mineral mixture + 10.5 salt (47.6 g DM)

B) 35 g barley + 2.1 g mineral mixture + 10.5 g salt + 4.2 g urea (51.8 g DM)

C) 35 g barley + 2.1 g mineral mixture + 10.5 g salt + 18.2 g EC feed (65.8 g DM)

D) 35 g barley + 2.1 g mineral mixture + 10.5 g salt + 18.2 g EC feed (70 g DM) + 4.2 g urea.

E) 220 g barley + 2.1 g mineral mixture + 10.5 g salt + 10.0 g urea (242.6 g DM).

Table 52. Expt 13.2. Mean composition of foods (g/kg DM)

	CP	CF	EE	NFE	Ash	Ca	P	Mg	Na
Roughages									
Barley straw	27.6	403.9	13.8	479.9	74.8	3.3	1.7	0.9	0.5
Hay I	64.8	294.0	14.7	571.4	55.1	3.0	1.8	1.0	0.6
Hay II	69.3	323.7	15.2	542.4	49.4	3.4	2.0	1.1	0.6
Supplements									
A	78.9	nd	nd	nd	263.3	4.7	4.1	9.5	75.8
B	267.6	nd	nd	nd	255.2	4.5	3.8	10.7	72.8
C	81.1	nd	nd	nd	278.8	17.5	3.7	10.4	71.8
D	236.8	nd	nd	nd	262.3	16.1	3.7	8.0	73.1
E Low	223.5	nd	nd	nd	81.8	2.4	3.9	3.2	18.8
High	219.8	nd	nd	nd	155.1	5.2	3.7	6.2	38.1

The treatments A to D given at the higher 140 g level of supplementation, were exactly doubled. At the higher level of supplementation only, the mineral and salt inclusions of treatment E were doubled to give 4.2 g mineral mixture and 21.0 g salt (the amounts of barley and urea given remained unchanged). Therefore, as in Expt 13.1, a low and high level of supplementation for each of the three roughages was given. In the present experiment the mineral mixture used was supplied by Rumenco Co. Ltd. and contained 127 g Ca, 36.1 g P, 233 g Mg and 1.1 g Na/kg. The composition of the supplements given is also outlined in Table 52. In contrast to Expt 13.1 the loose mix was analysed rather than the individual constituents (although the composition of EC feed was equivalent to that given in Table 49). All the supplements were given as in Expt 13.1 once daily (10.00 hr).

Each treatment was given to the sheep according to the Latin square design for periods of 17 days. The final 7 days of each treatment was used for the measurement of voluntary roughage intake and diet digestibility, following 10 days of introduction to each roughage/supplement combination. The wethers were equipped for quantitative faecal collections with harnesses and rubberised canvas bags and the resulting 7-day faecal collections were sampled according to Method 2 in the Introduction (Page 71). The DM, ash, energy and nitrogen contents of the faeces were then determined.

On day 16 of each treatment period the sheep were bled (to determine calcium, phosphorus, magnesium, urea and FFA concentrations) at 11.00 hr (two hours after giving the supplements). Upon completion of each 17-day treatment period the sheep were weighed.

Analysis of data

The results for each Latin square were analysed using a multivariate-analysis of variance, computer program (Biomedical computer programs, no. BMD x 63). The mean values for the treatments within each Latin square were expressed in relation to the roughage alone values, on a plus or minus basis. These are referred to as contrasts with roughage alone (RA) in the tables. As the roughage alone treatment was not an integral part of the Latin square design and may have been biased by its occurrence at the end of the 85 days (total duration) of each Latin square, a separate standard error estimate (SE of contrast) had to be calculated, before comparisons between the roughage alone treatment and those within the Latin squares could be made. For comparisons between the treatments within each Latin square, a second standard error (SE of contrast differences) of lower magnitude was used. In this way, statistically valid comparisons could be carried out between the five treatments of each Latin square (supplementation) and also with roughage alone (no supplementation). A studentised range test (16 degrees of (freedom) was used to indicate significant differences between the comparisons where appropriate. Where the studentised range test indicated significant differences, the usual t-test was used to examine individual treatment differences. The effect of the treatment in all Latin squares was further compared using Kendall's coefficient of Concordance (Siegel, Non-Parametric Statistics), which enabled the overall ranking of the supplements given to be examined.

Results

One wether given the barley straw, low level of supplementation treatments, became progressively weaker during period 5 and was removed from the experiment. The treatment was repeated with a comparable spare animal. All wethers given barley straw lost weight, -17.3 and - 10.5% of their initial live weight for the low and high levels of supplementation, respectively. This live-weight loss increased to -25.3 and - 20.1% after the sheep had been given straw alone for a further 17 days.

All wethers given hay plus the supplements gained live weight. When hay I was given the mean live-weight gains were 9.3 and 17.0% of the initial live weight at the low and high levels of supplementation, respectively. When this hay (I) was given without supplementation for a further 17-day period, the sheep lost weight to give an overall gain over the 102 days of the experiment of 2.7 and 13.0%, respectively. The wethers given hay II gained a mean 12.0 and 8.0% live weight at the low and high levels of supplementation, respectively, over an 85-day period. When no supplementation was given for a further 17 days the sheep lost live weight, to a level no different from the initial starting weight. The mean pattern of live weight changes for the six periods (102 days) is presented in Fig 25 for the various roughages and levels of supplementation.

The mean effect of the individual supplements on live-weight changes of the sheep during the 17-day periods when these were given, is outlined in Table 53. Supplementation invariably increased live-weight gain compared to roughage alone, but the quality of the underlying roughage given was more important in determining the magnitude of any live-weight change. With straw there was only one average live-weight gain (treatment E at the low level of supplementation) out of the 10 treatment/supplement combinations. On hay the 20 combinations produced no live-weight losses, on average. Significant differences between the roughage alone and/or between the treatment/supplement combinations occurred only for the barley straw, low level of supplementation, Latin square. The live weight-loss on roughage alone was significantly greater than for all the supplementation treatments. Treatment E (220 g barley + 10 g urea) gave a significantly ($P < 0.05$) lower live-weight loss than A (barley, mineral, salt). Treatment C (barley, mineral, salt, EC feed) was better than RA, and slightly worse than E. There was no clear overall effect of any of the treatments on live-weight change as

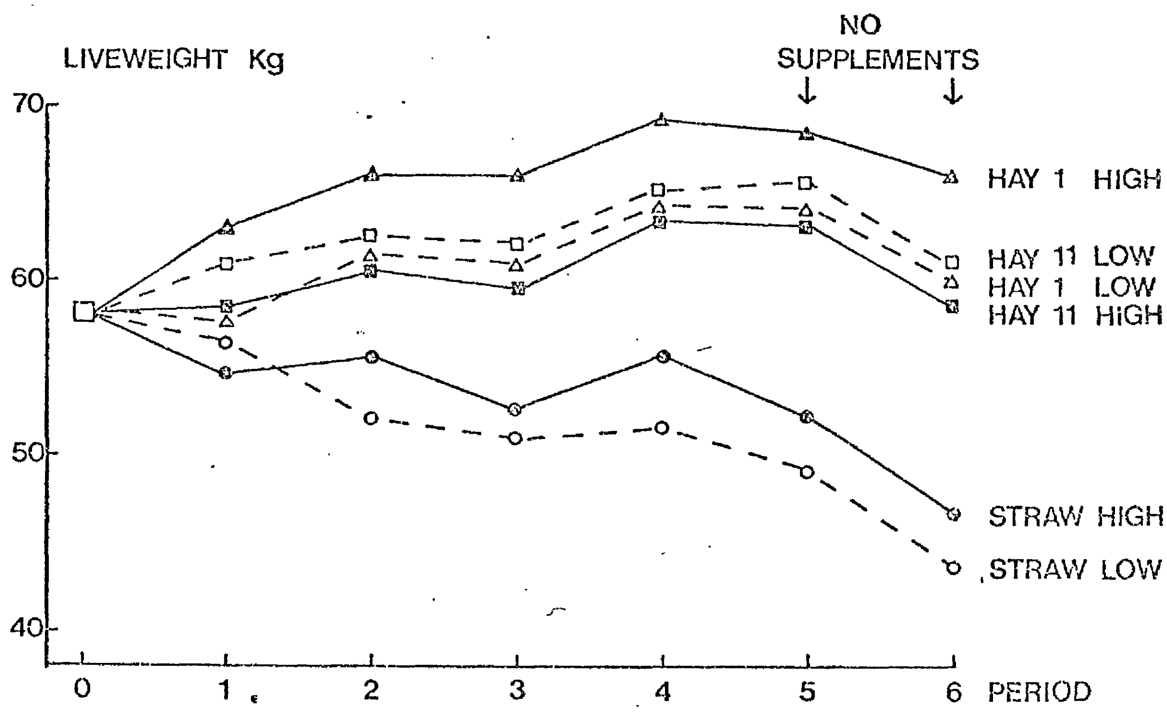


Fig.25 Expt 13.1 Mean changes in sheep live weight (kg) for each roughage/level of supplementation combination during the various 17-day periods of the Latin square and also when the roughages were given unsupplemented.

indicated by a non-significant value for Kendall's coefficient of concordance.

Table 53. Expt 13.2. Mean live-weight changes (kg) (5 sheep/group)

		Barley straw		Hay I		Hay II	
Level		L	H	L	H	L	H
RA		-4.5	-6.8	-3.8	-2.3	-5.8	-4.2
Contrasts with RA	A)	1.3	4.6	4.0	7.0	7.2	5.6
	B)	2.5	5.2	3.8	3.7	5.8	4.2
	C)	2.3	4.8	4.2	2.4	7.4	5.8
	D)	0.5	6.7	5.8	5.7	6.0	4.4
	E)	5.5	6.6	6.6	2.7	7.6	6.0
SE of contrast		2.0	3.4	2.3	3.1	2.2	2.2
SE of contrast diffs		1.2	1.7	1.4	2.5	1.6	1.5
Studentised range		5.89**	1.75	2.83	2.60	1.59	1.70

Significance RA < E***; B,C**, D*

C > D*

The mean effect of the individual supplements on the voluntary intake of the roughages given, relative to no supplementation is outlined in Table 54. Although no individual square showed up a difference between the five treatments, or when compared with roughage alone, if the overall effect of the treatments was examined (30 comparisons; 6 Latin squares x 5 treatments) there was a strong suggestion of a difference (5% evidence of non-uniformity). The overall ranking of the treatments was B, E, A, D and C. Supplementation increased appetite in

Table 54. Expt 13.2. Voluntary roughage intake (g DM/head/day) (5 sheep/group)

		Barley straw		Hay I		Hay II	
Level		L	H	L	H	L	H
RA		652	753	1320	1388	1314	1272
Contrasts with RA	A)	100	149	38	16	84	68
	B)	168	35	18	106	36	60
	C)	104	13	-50	-76	-52	34
	D)	124	109	-34	-8	32	34
	E)	152	133	10	124	20	58
SE of contrast		83	110	80	66	114	114
SE of contrast diffs		28	67	56	66	68	73
Studentised range		3.43	2.87	2.22	2.83	2.83	2.48

Table 55. Expt 13.2. DM digestibility % (5 sheep/group)

RA		37.5	40.8	58.1	54.5	54.7	54.5
Contrasts with RA	A)	8.6	8.6	4.2	4.5	1.0	0.6
	B)	10.5	6.9	3.5	7.3	2.7	9.0
	C)	7.1	8.3	2.4	4.4	2.6	5.8
	D)	7.2	10.7	1.2	5.9	0.8	4.3
	E)	10.4	12.9	4.5	8.4	4.8	6.9
SE of contrast		3.6	2.6	3.1	2.4	2.2	3.0
SE of contrast diffs		2.0	2.1	1.7	1.8	1.7	2.4
Studentised range		2.39	3.97^{+}	2.71	3.06	3.44	4.99***
Significance							RA < B**, E* A < B**, E, C*

every case on straw and in most cases with the hays. On five of the six occasions, when a voluntary intake was measured less than for roughage (hay) unsupplemented, EC feed (treatments C and D) was involved. The largest increases in voluntary intake were with the barley straw (low level of supplementation) treatments B and E where the increases were 26 and 23%, respectively. An increase of 20% in straw consumption was measured for treatment A at the high level of supplementation. Treatment B at the high level of supplementation of the barley straw was little different from the voluntary intake with roughage alone, this was mainly due to a very low individual intake on this treatment in Period 1.

Supplementation invariably increased DM digestibility, most markedly on the barley straw treatments but still quite impressively for the two hays. Significant differences either within the individual Latin squares or between treatments within the Latin squares and the respective roughage alone estimates, occurred only once. Treatments B and E (high level) plus ad libitum hay (II) gave a significantly ($P < 0.01$ and $P < 0.05$) increased DM digestibility, than when hay II was given alone. The DM digestibility increased from 54.5 to 63.5 and 61.4 for treatments B and E, respectively. Treatment A in the square gave a significantly lower DM digestibility of the combined diet than treatments B, E or C (Table 55). When the overall effect of the 5 treatments on DM digestibility was examined it was concluded that they were not equally effective (significant at $P < 0.01$). The ranking of the treatments was E, B, A, D and C. Treatment C was certainly better than RA and somewhat worse than E.

The OM digestibility of the combined diet relative to roughage alone was increased in every case by supplementation. There were no significant differences between treatments within any of the individual Latin squares at the 5% level or greater, although three of the six squares showed significant differences at the 10% level (Table 56).

Table 56. Expt 13.2. OM digestibility % (5 sheep/group)

		Barley straw		Hay I		Hay II	
Level		L	H	L	H	L	H
RA		39.9	43.0	60.6	57.4	55.7	55.6
Contrasts with RA	A)	9.4	8.0	2.3	5.1	0.0	0.5
	B)	10.7	6.7	1.8	6.0	2.1	7.9
	C)	4.5	6.6	0.7	2.3	1.7	2.3
	D)	5.6	10.2	2.0	3.7	2.0	3.1
	E)	9.6	11.3	3.0	2.4	2.2	6.2
SE of contrasts		3.7	3.5	2.9	2.7	2.5	3.1
SE of contrast diffs		2.2	2.2	1.6	2.1	2.0	2.5
Studentised range		4.02+	3.05	4.28+	2.43	1.6	4.14+

Table 57. Expt 13.2. Energy digestibility % and the ME intake MJ/head (5 sheep/group)

RA	36.8(3.7)++	42.2(4.3)	54.2(10.2)	53.5(10.7)	51.0(10.0)	51.1(9.7)
Contrasts with RA						
A)	8.7(5.2)	8.3(7.0)	5.2(11.8)	2.9(11.9)	2.2(11.4)	2.9(10.0)
B)	10.4(5.9)	4.2(5.8)	4.3(11.6)	4.8(13.1)	3.1(11.2)	9.2(11.6)
C)	7.4(5.2)	4.5(5.8)	3.7(11.1)	0.4(10.9)	2.7(9.6)	7.5(11.6)
D)	7.2(5.3)	7.1(6.8)	0.7(10.5)	3.2(12.0)	2.4(11.1)	3.5(10.9)
E)	11.2(7.1)	9.1(8.2)	5.5(13.2)	8.0(15.3)	4.1(12.8)	6.7(12.3)
SE of contrasts						
	3.7	4.6	2.6	3.3	3.3	4.1
SE of diffs						
	2.5	2.5	2.1	2.4	2.7	2.9
Studentised range						
	2.24	2.76	3.18	4.52*	1.04	3.06

RA < E*

E > C**, A*

+ Significant differences between the treatments at the 10% level

++ ME intake MJ.

There was some suggestion of non-uniformity (significant at $P<0.05$) of the treatments, when the overall effect on OM digestibility was examined. Treatment E seemed best followed by B, D, A and C. In four of the six square Treatment C (barley, mineral, salt, EC feed) gave a OM digestibility considerably below that of treatment A (barley, mineral, salt).

Table 57 includes estimates of the percentage energy digestibility of the roughages when unsupplemented and of the combined diet when supplementation occurred. The calculated total ME intakes (DE x 0.81) for the individual treatments are also included.

The energy digestibility of the combined diet relative to roughage alone was everywhere raised by supplementation, with evidence of a systematic difference between treatments ($P<0.05$). Treatment E seemed best, followed by B, with A, C and D together. The treatment noticeably improved the energy digestibility of the combined diet, relative to roughage alone and hence total ME intake in most cases even with good hay. Significant differences were only obtained for one individual square, (hay I high level of supplementation). In this square Treatment E gave a significantly ($P<0.05$) higher energy digestibility (61.5%) when given in combination with hay I, relative to the unsupplemented hay digestibility (53.5%). Treatment E also gave a significantly higher digestibility of the combined diet than treatments C and A. The DE contents of the roughages (mean of 10 sheep) were estimated to be 7.0, 9.5 and 9.4 MJ DE/kg for the barley straw, hay I and hay II, respectively. The ME contents (DE x 0.81) were then 5.7, 7.7 and 7.6 MJ ME/kg, respectively.

The nitrogen digestibility of the diet was always raised by supplementation on the barley straw treatments. For both hays, nitrogen digestibility was always raised by treatments B and E and lowered by C. The largest increases in nitrogen digestibility were obtained with the straw diets, the nitrogen digestibility was still negative with treatments A and C. Every individual square gave evidence of significant differences between the treatments. On the barley straw, low level of supplementation square, treatments E, B and D were significantly better than C and A (all were better than roughage alone). Likewise, at the high level of supplementation, for barley straw diets a similar significant effect of the treatments was recorded. On hay I diets (low level of supplementation) treatment E was significantly higher in nitrogen digestibility of the combined diet than either C, A or D. Treatment B was also significantly better than either C or A. At the higher level of supplementation, treatment E showed a significantly higher nitrogen digestibility than treatments C and A. Treatments B and D were also better than C.

On hay II diets, irrespective of level of supplementation, treatment E was significantly better (Table 58) than either C or A and also D (high level only). Treatment B gave a significantly greater nitrogen digestibility than C, at both levels of supplementation and A and D at the higher level only. The overall effect of the five treatments on nitrogen digestibility showed that E was clearly best followed by D and B, then A and C. There was significant evidence of non-uniformity between the treatments ($P < 0.01$). Treatment C gave a higher nitrogen digestibility of the combined diet than with roughage alone on straw diets, but slightly lower when given in combination with the hays. The amounts of CP apparently digested when the roughages were given unsupplemented were -12.5, 28.1 and 30.2 g CP/kg DM for barley straw, hay I and hay II, respectively. The digestibility of CP in hay of very low digestibility (MAFF et al. 1975) is 43%, this is in very close agreement with the mean (20 sheep) nitrogen (CP) digestibility of the hays used here, 43.5%. Therefore the amounts of CP in the hays apparently digested were an

Table 58 Expt 13.2 Nitrogen digestibility % and the amounts of CP in the diets apparently digested compared with calculated DCP intakes (g) (5 sheep/group)

		Barley straw		Hay I		Hay II	
Level		L	H	L	H	L	H
RA		-55.0	-35.8	47.7	38.9	41.2	46.0
Contrasts with RA	A)	42.0	29.7	- 6.4	2.3	0.3	- 7.5
	B)	73.5	70.7	0.5	8.9	8.3	11.7
	C)	19.2	36.8	-10.2	- 4.3	- 6.4	- 4.6
	D)	74.1	72.9	- 3.5	9.0	3.5	- 0.6
	E)	99.0	82.5	5.7	15.8	12.8	13.4
SE of contrast		16.3	9.7	7.5	8.1	7.3	7.4
SE of contrast diffs		14.0	6.6	3.2	4.2	5.4	4.6
Studentised range		8.09***	11.30***	7.05***	6.76***	5.00**	4.33*
Significance		RA < A,B,C,D,E***, E > C,A*** B,D > C**,A*	RA < A,B,C,D,E*** E,B,D > A,C***	E > C***,A**,D* B > C**,A*	E > C***,A** B,D > C**	E > C**,A*,B < C*	E > A***,C,D** B > A***,C**,D*

Amounts of CP in the diets apparently digested compared with calculated DCP intakes (g)

		Barley straw L	Barley straw H	Hay I L	Hay I H	Hay II L	Hay II H
RA		-10 (6)	- 8 (7)	41	35	37	41
Treatments	A)	- 3 (8)+	- 2 (12)	38 (45)	41 (41)	41 (43)	35 (44)
	B)	7 (20)	17 (35)	48 (56)	60 (67)	53 (53)	69 (72)
	C)	- 9 (8)	0 (11)	33 (42)	33 (38)	35 (42)	40 (45)
	D)	7 (20)	21 (35)	44 (54)	59 (64)	50 (54)	54 (69)
	E)	34 (51)	38 (52)	74 (87)	84 (84)	81 (86)	83 (85)

+ Calculated DCP intakes.

accurate reflection on DCP content, when unsupplemented.

Table 58 also includes details of the amounts of CP apparently digested on the roughages alone and with the treatments of each individual Latin square. These have also been compared with a calculated DCP intake, assuming urea to be fully digestible, the DCP content of barley to be 82 g/kg and the DCP contents of the hays to be as calculated in vivo, when unsupplemented. The DCP of the barley straw was assumed to be 9 g/kg (a straw containing 38 g CP/kg will give a DCP of 9 g/kg; MAFF et al. 1975) or 24% of the CP in the straw is digestible.

As in Expt 12.3 with cows given predominantly straw diets (oat), the wethers in the present experiment had a negative nitrogen digestibility, when straw alone and also treatments A and C (no urea) were given. The amounts of CP in the straw diets apparently digested showed a wide divergence from the calculated (ARC, 1965) DCP intakes. When the hay roughages were supplemented, the amounts of CP apparently digested and the calculated DCP intakes were generally in close agreement, in contrast to the straw. When treatments A and C were compared (which only differed in that C contained EC feed), the amounts of DCP digested on average were 39 and 35 g, respectively. Only for one square was C better than A and in all 4 squares C gave a lower amount of CP apparently digested, than for no supplementation of the hays. Treatments B and D also differed in that D included EC feed. In every individual square when hay roughage was given, treatment D (plus EC feed) gave a lower amount of CP apparently digested compared with treatment B.

Table 59 includes details of the plasma urea and blood phosphorus concentrations for the sheep in the individual Latin squares. Plasma FFA, calcium and magnesium concentrations were also measured and analysed but it was considered unnecessary to tabulate these values due to the small amount of additional information they contributed to the

Table 59 Expt 13.2 The effect of the supplements given on blood parameters

	Urea mg/100 ml						Phosphorus mg/100 ml					
	Barley straw		Hay I		Hay II		Barley straw		Hay I		Hay II	
Level	L	H	L	H	L	H	L	H	L	H	L	H
RA	8.9	10.2	20.8	22.9	22.1	25.6	5.6	6.0	5.2	6.0	5.9	7.1
Contrasts with RA A)	0.7	- 2.9	- 8.5	- 8.7	-11.3	-10.0	-0.1	-0.3	0.7	0	0	-1.3
B)	7.8	9.7	0.7	4.0	- 4.5	- 1.7	0.4	-1.8	0.9	-0.8	0.1	-1.0
C)	0.5	1.5	- 7.3	- 8.2	- 8.5	- 5.0	0.2	-0.1	0.4	-0.1	0.2	0.1
D)	4.1	7.1	- 5.0	- 1.0	- 3.9	0.6	0.4	-0.3	0.2	-0.1	0.1	-0.3
E)	10.3	9.9	2.9	5.5	- 0.1	- 2.1	0.3	-0.7	0.5	0.7	0.2	-0.2
SE of contrast	2.5	4.7	3.0	4.1	4.0	5.7	0.6	0.8	0.6	0.9	0.6	0.9
SE of contrast diff	2.4	3.6	2.2	2.6	4.0	2.3	0.6	0.5	0.5	0.6	0.6	0.9
Studentised range	5.82**	5.0**	7.45***	7.72***	4.00	6.38**	1.02	4.93**	2.11	3.61	0.75	2.45
Significance	RA < E*** A** E > C***, A** B > C** A	E,B > A**, C*	RA > A*, C, E > A***, C, D*** B > A***, C**, D*	RA > A*, B, E > A, C*** E > D*		E,B > A** D > A*** C*		RA > B* B < A*, C*, D, E*				

experiment. The FFA concentrations were generally lowered by supplementation but there was no clear evidence of any treatment being different from the others. There was considerable variation in FFA concentrations between animals on each treatment, due to either the erratic biological nature of this parameter, or alternatively a substantial analytical error.

Plasma magnesium concentrations were everywhere decreased by supplementation with no clear pattern emerging between the individual treatments. The blood calcium concentrations (which were always within the normal range) were always lowered by supplementation, but there was no clear indication of which treatment had the most effect. There were generally greater changes in blood calcium concentrations of the sheep when given the hays (relative to roughage alone) than with barley straw.

Plasma urea concentrations were generally increased by supplementation of the barley straw roughage, and generally lowered with hay II. The effect of supplementation on the plasma urea concentrations of sheep given hay II compared with supplementation was inconsistent. As expected the treatments (B, D and E) supplying urea gave higher plasma urea concentrations than those supplying no urea (A and C). When the overall effect of the five treatments on plasma urea concentrations was examined there was evidence of non-uniformity at $P < 0.01$. Treatment E gave the highest urea levels, followed by B and D, then C and A. Treatment C generally gave higher levels than A but the effect was lost when urea was already given i.e. treatment D was not higher than B. The blood phosphorus concentrations were all within the normal range. There was also little difference in blood phosphorus between the roughages, irrespective of period of the Latin squares.

The data generated in this experiment was further examined with respect to correlations between the 11 parameters studied. This involved analysis of the residual sum of squares and cross-products matrix (with equal period effects assumed). The only significant correlations were between DM, OM and energy digestibility, with each other. Voluntary roughage intake and DM, OM and energy digestibility. A third set of correlations were obtained between DM, OM and energy digestibility with blood phosphorus.

Discussion

In contrast to Expt 13.1, the digestibility results given are for the combined roughage/supplement diet in the present experiment. The digestibility of the combined diet should usually exceed that of the roughages given alone, due to greater digestibility of the supplement portion of the diet, (mainly barley) irrespective of any indirect improvement of roughage digestibility due to the supplements. The lower the digestibility of the roughage the greater the improvement in digestibility when the combined diet is given. In Expt 13.1, when roughage allocation was far below appetite, particularly for the hays, the supplements given formed about 10 and 19% of the total diet at the 60 and 120 g levels of supplementation, respectively. Therefore an attempt was made to eliminate the direct effect of improved, combined diet digestibility, by making allowance for the faecal outputs due to the supplement constituents. It was then intended to examine the estimated digestibilities of the roughages for indirect effects of the supplement ingredients, none of which were positive.

In this present study (Experiment 13.2) the roughages were allocated ad libitum and the supplements given formed a lower proportion of the total DM intake. Therefore it was considered unnecessary to eliminate the faecal constituents of the supplement ingredients and digestibility comparisons between the treatments were made on the combined diet.

The ME maintenance requirement of housed sheep (MAFF et al. 1975) weighing about 60 kg is 6.8 MJ. The barley straw when given unsupplemented,on average only supplied 59% of this requirement (4.0 MJ ME). Supplementation increased the ME intake by 40 to 60% (1.5 to 2.2 MJ) and 35 to 63% (1.5 to 2.7 MJ) for the 70 and 140 g levels of Rumevite supplementation,respectively. The amounts of barley given in these supplements (35 and 70 g DM) would only supply 0.5 and 1.0 MJ or ME. Therefore the supplements given must have indirectly increased ME intakes by increasing the utilisation of the barley straw, as indicated by the increased straw intake on all treatments and also increased digestibility. It was calculated that between 25 to 46 and 11 to 40%, at the 70 and 140 g levels of supplementation,respectively ,of the increase in ME intake was due to the indirect improvement of straw utilisation. The treatments (C and D) containing EC showed no improvement over and above that of barley with or without urea (treatments A and B).

Treatment E, unconnected with either the formulation of Rumevite or level of intake realistically possible from a Rumevite block, improved ME intake in both of the barley straw Latin squares by 90% (4.0 MJ). This reflected the provision of additional ME in the barley supplement,rather than an indirect improvement of energy intake via increased straw utilisation. Even though all the treatments given improved ME intake, only the more substantial input of barley (treatment E) created a plane of nutrition always above maintenance. At the higher level of Rumevite supplementation, treatments A (barley) and D (barley, urea, EC feed) gave a plane of nutrition at or around maintenance.

For all combinations of supplements or when given alone, both hays provided a plane of energy nutrition at least 41% greater than maintenance. This was reflected in the periods of the Latin squares by a progressive live-weight gain. When the hays were given alone the sheep lost live weight even though they were receiving about 40% more ME than was received for maintenance of 60 kg sheep. Two possible explanations for this inconsistency may be appropriate. Firstly, the mean live weight of the sheep had increased upon completion of the Latin squares to about 65 kg, which meant they required 7.3 MJ ME for maintenance. Secondly, in all the periods of the Latin squares considerable quantities of salt had been consumed which probably created an increased weight of fluid in the rumen. When roughage alone was given the absence of salt would decrease water intake and perhaps the weight of gut contents, resulting in the rather high decreases in live weight recorded. Together, these two factors may explain the discrepancy between ME intake and live-weight loss.

The supplements given, based on the formulation and ingredients of Rumevite feedblocks, at a range of levels commonly attained by sheep in a practical situation, only marginally increased the ME intakes of the sheep, relative to those with unsupplemented roughage. The ME intake of sheep on hay I (65 g CP/kg) was increased by between 3 to 16 and 2 to 12% by the treatments given at the 70 and 140 g levels, respectively. The ME intake of sheep on hay II (69 g CP/kg) was lowered by 4% by treatment C (barley, EC feed) at the 70 g level of supplementation and increased by a maximum of 14% by the other treatments. At the 140 g level of supplementation the treatments given, increased ME intake by between 3 and 20%. Most of the increases in ME intake when supplementation occurred were due to the additional ME (0.5 and 1.0 MJ) supplied by the barley in the supplements. Any increased ME intake arising from increased hay utilisation was therefore small and not significant.

The higher plane of nutrition treatment, supplying over 200 g barley DM plus 10 g urea improved the ME intake of sheep on diets based on hay I and II by 36 and 28%, respectively. This treatment should have supplied about 4.0 MJ ME directly above the ME intake from roughage alone. On average the ME response from this treatment was only 3.3 MJ ME, part of which may have been due to an indirect effect on roughage utilisation. Therefore the ME derived from this 'higher plane of nutrition' treatment was not as great as intended for the hay roughages.

The DCP requirements for maintenance for crossbred sheep weighing 60 kg and consuming either 0.72 or 0.88 kg DM/head/day are 37 and 39 g, respectively (ARC, 1965). The sheep consuming barley straw alone had calculated DCP intakes of about 6 or 7 g. Only for the treatment supplying 10 g of urea plus over 200 g barley DM, did calculated DCP intakes exceed requirements, although treatments B and D at the 140 g level of Rumevite (35 g DCP) supplementation approached the required intakes. The treatments containing additional urea increased CP content of the combined straw-supplement diet from 3.1 and 3.4 (barley supplement alone) to 4.8 and 6.2% at the 70 and 140 g levels of supplementation, respectively.

The DCP requirements for maintenance for the sheep given the hays were 44 to 47 g DCP/head/day (ARC 1965). Even when given unsupplemented, the mean DCP intakes for all the 20 sheep on hay (39 g) was only marginally below the required intakes. Supplementation usually increased the DCP intakes to well in excess of the requirement for maintenance. However there was a tendency for treatments containing EC feed to lower the DCP intake, relative to similar treatments containing barley alone or barley plus urea without EC feed. Due to the satisfactory plane of nutrition given in this experiment any detrimental effect of EC was not of biological significance.

All the blood parameters measured showed no deviation from the normal ranges, indicative of no mineral deficiency occurring in the diets given. The plasma urea (hays only), calcium, magnesium and sometimes phosphorus concentrations were lower when supplementation was given, compared with roughage alone. This may be explained by the breakdown of body tissues. When roughage alone (hay) was given to the sheep a small deficit of DCP in the diet occurred, with a likely net result of catabolism of body tissues releasing amino acids and eventually (via nitrogen recycling) creating an elevated plasma urea concentration. This increase in plasma urea when no supplementation was given did not occur on the straw diets due to the very low nitrogen content of the roughage. The upgradation in nitrogen status when the supplements were given was more substantial for the straw diets than for the hays.

Similarly, a shortage of phosphorus when the roughages were given unsupplemented would create a demineralisation of bone under the action of parathyroid hormone, resulting in increased phosphorus in the plasma. A concomitant increase in plasma calcium and magnesium would then occur.

In the previous experiment, one of the reasons put forward to explain the failure of the supplements given, to improve roughage digestibility, was that a possible deficiency of phosphorus overshadowed all other effects. The intakes of phosphorus were as low as 12 mg/kg live weight. In the present experiment on the straw alone, phosphorus intakes were about 20 mg/kg live weight, yet no blood plasma phosphorus concentrations were measured. The maximum phosphorus intakes on barley straw was 41 mg/kg live weight. Therefore it does not appear that phosphorus intake per se contributed significantly to the results obtained in either experiment.

Nowhere in either the present experiment or Expt 13.1 was the claim made by the manufacturers of Rumevite (i.e. that EC feed alone increases the utilisation of roughages by up to 50%, over and above any improvement due to the barley (energy) or protein (urea) in the block) substantiated. Any significant effect of EC feed on roughage utilisation was always negative (particularly on nitrogen digestibility of the hays) which is again in agreement with the work of Unsworth et al. (1966). Of all the treatments given, that containing barley and EC feed invariably ranked last, behind the others in terms of voluntary intake and digestibility.

It is concluded that the claims made for EC feed are spurious and the small amount of energy and protein it contributes to the block (Table 49) is far outweighed by its depressing effect in roughage utilisation. The exact reasons for the adverse effect of EC feed on roughage utilisation are not yet clear. In Expt 13.1 it was suggested that the combination of sodium and potassium in the diet may together effect a depression of digestibility. The concentration of sodium in the diets given in the present experiment never exceeded about 12 g Na/kg. (The potassium concentrations in the roughages given were not measured). At this level it would be highly unlikely for sodium to have a detrimental effect on roughage digestibility, particularly as the sodium concentrations in the hays (which were most affected by treatments containing EC feed) only contained at the most about 7 g Na/kg.

EC feed has a high pH (10 to 11) and appeared to be unpalatable to some sheep. The lowest voluntary intakes were obtained overall on the barley EC feed treatment, which may have reduced the palatability of the roughage and thereby decreased intake. A more subtle physiological reason would be required to explain the effect of EC feed on digestibility. This requires further investigation.

Although it was shown that supplements consistent with the formulation of Rumevite feedblocks could improve the utilisation of barley straw and improve ME intake of sheep appreciably by both indirect (roughage utilisation) and direct (ME in the supplements) methods, the relevance of this to the practical UK situation where blocks are given is open to debate. The cereal straws are mainly given to beef cattle or dairy replacement stock under UK winter conditions. It is seldom for supplement-type blocks and straw to be given alone, unless a plane of nutrition well below maintenance is acceptable. Additional energy is usually supplied as barley, silage and/or arable by-products. In many situations it is just as convenient and far cheaper to 'hand-feed' all the supplementary nutrients. Therefore although it is possible for a supplement-type feedblock to increase ME intake to around maintenance, a truly productive situation is not reached unless substantially increased amounts of energy are given, as occurred in treatment E in Expt 13.2.

Under South African veld conditions the supplement-type feedblock may be very suitable. The roughage available is uniformly low in nitrogen (20 to 30 g CP/kg), climatic factors are minimally variable and a controlled amount of weight loss during winter is generally acceptable. As a result the production cycle for finishing cattle is considerably longer than in the UK. The so called 'store period' on UK farms when cattle may lose considerable live weight during wintering on sub-maintenance diets, is nowadays undesirable economically. Supplement-type feedblocks are principally designed to be used in these 'store' phases of the production cycle, as their low potential nutrient intake limits their usefulness in more productive situations.

It is likely that most blocks given to sheep are used in a hill or upland situation, during the final 6 to 8 weeks of pregnancy and in early lactation. On most hill farms this coincides with months March and April, although blocks may be given earlier if the winter is particularly severe. The nature of hill farming is very diverse and hardly any two situations are exactly similar. Before any measure of the likely benefit of the supplement-type feedblocks can be gained information is required on the qualitative and quantitative nature of the diet of the hill ewe in various situations. Sheep graze with a great degree of selectivity, therefore it is misleading to estimate nutrient intake from what is left on the pasture rather than what has been consumed. Eadie (quoted by Armstrong and Trinder, 1966) has estimated that the CP content of the diet selected by the hill ewe is never less than 87 g/kg. The hays used in Expt 13.2 contained 65 to 69 g CP/kg yet the improvement in ME intake due to increased roughage utilisation was only marginal. If the estimate of CP in the ingested diet given by Eadie is reasonable in the majority of situations, any improvement in ME intake derived from increased roughage utilisation will be negligible. Any improvement in ME intake will arise directly through the feedblock ingredients per se.

However the work by Tait, Milne and Russel (1976) has shown that on predominantly heather (Calluna Vulgaris L. Hull) diets small inputs of supplementary nitrogen and/or energy can result in considerable improvements in heather intake and digestibility. It was stated that heather contained relatively large quantities of tannins which appear to form insoluble complexes with proteins in some situations. Therefore on predominantly heather hills the use of a supplement-type feedblock may be justified. Nevertheless in more productive situations (lambing percentage >100), additional ME supplied directly from the feedblock ingredients is usually essential to augment the indirect increase (if any) in ME intake via increased roughage utilisation.

Conclusions

In many of the experiments carried out in this thesis, a principal claimed advantage for 'self-help' feedblocks, the more precise individual supplementation than with 'hand-fed' nutrients, has been shown not to be the case. Also the claims made that animals will regulate their intakes of feedblocks according to the qualitative and quantitative nature of the other dietary ingredients have been shown not to be strictly correct. There appears to be no evidence to suggest that ruminants given feedblocks will manifest a 'nutritional wisdom' particularly for magnesium or urea, as is sometimes implied to be the case. In Section 4 it was shown that there was no particular significance to be placed on the 'special unique ingredient' in Rumevite feedblocks known as EC feed which has been extensively claimed to increase the utilisation of all roughages by considerable amounts (over and above any response to NPN). There was a strong suggestion that in most cases EC feed had a detrimental effect on roughage utilisation.

In Section 2 (in particular) and throughout the rest of the thesis (in general) it was shown that feedblocks could not be relied upon to give even a remotely constant intake between days. Numerous factors appeared to influence total group intake of feedblocks including climatic conditions. 'Hand-feeding' is not influenced from the majority of these factors and total amount allocated is determined by the stockfeeder rather than the stock themselves.

A factor of particular relevance to the farmer yet not considered so far in this thesis is the cost of nutrients in feedblocks compared to other sources of supplementary nutrients such as proprietary compounds. The majority of feedblocks at present cost between £120 to £160/tonne compared to proprietary sheep compounds at £110/tonne and barley at about £85/tonne. Therefore feedblocks are expensive sources of nutrients, particularly energy. The estimated ME value (9 to 11 MJ

ME/kg DM, Table 1) is considerably below that for compounds (about 12.0 MJ ME/kg DM) and barley (13.7 MJ ME/kg DM). The lower values for feedblocks reflect mainly the proportion of binders and unpalatable ingredients (e.g. high levels of salt) which they contain. The proportion of ash in the feedblocks examined in this thesis varied from 200 to 400 g/kg DM, most of which would be of no nutritional benefit to the animal. It was estimated that the cost of 1 MJ ME from a supplement-type block (higher ash, ME = 9 MJ/kg DM) was about 1.7p, the cost of 1 MJ ME from the higher intake substitute-type blocks was estimated to be between 1.4 and 1.5p, a difference of between 12 to 18%. The cost of 1 MJ ME from either a 140 g CP/kg sheep cob or a 200 g CP/kg sheep concentrate would be approximately 1·1 to 1·2p. In most situations energy is the most important supplementary nutrient required. As indicated in Section 4, in more productive situations additional energy from the block ingredients per se is vital to the success of the system, as indirect increases in ME intake (if any) via enchanced roughage utilisation are usually inadequate to even partially meet ME requirements.

In refuting many of the claimed advantages and being somewhat critical of feedblocks in general, this thesis may seem unduly pessimistic towards their suitability in UK animal production systems. To the contrary, there appear to be at least four main reasons for using blocks rather than cheaper, more conventional 'hand-fed' nutrients. Firstly, feedblocks allow supplementary nutrients to be given to stock kept on less accessible areas, where other forms of feeding are quite impractical. It is likely, however, that a varying proportion of the stock may not make adequate use of this source of supplementation. Secondly, when feedblocks are given in extensive grazing situations (e.g. hill or upland) the stock remain on their grazing area which may enable them to make fuller use of the roughage available, without the disruptions caused by 'hand-feeding.' This point requires further investigation.

The practical use of feedblocks was developed in South Africa where they were shown to reduce weight loss at range grazing in continuous dry seasons. Their capacity to improve animal production in the more variable British conditions does not necessarily follow.

Thirdly, on extensive grazing the risk of mismothering after lambing may be reduced by giving blocks compared with 'hand-feeding.' This allows supplementary nutrients to be given during the critical period of early lactation which traditionally does not happen at present. Finally, in less extensive situations farmers may feel that any convenience aspects of giving blocks justifies their extra cost.

In conclusion, feedblocks are not substitutes for good husbandry. The converse appears to be more the real case, i.e. that good husbandry is instrumental in ensuring that the block system works, particularly under hill conditions. Here, the siting of blocks and frequent observation of the pattern of block consumption may determine the success or otherwise of an expensive input of additional nutrients. The case for the use of feedblock has been somewhat overstated especially by certain manufacturers via their advertising literature, which may have detracted from the real and considerable merits of the feedblock system.

BIBLIOGRAPHY

Altona, R.E. (1966) Outlook on Agriculture 5 : 22.

Altona, R.E., Rose, C.J. and Tilley, T.J. (1960) S. Afr. J. Agric. Sci. 3 : 69.

A.R.C. (1965) Agricultural Research Council. The Nutrient Requirements of Farm Livestock No.2 Ruminants London H.M.S.O.

Armstrong, D.G. and Trinder, N. (1966) J. of University of Newcastle-upon-Tyne Agric. Soc. 20.

Arnold, G.W. and Maller, R.A. (1974) Anim. Prod. 19 : 309.

Beames, R.M. (1959) Queensland J. Agric. Sci. 16 : 223.

Beames, R.M. (1963) Queensland J. Agric. Sci. 20 : 213.

Beames, R.M. and Morris, J.G. (1965) Queensland J. Agric. Anim. Sci. 22 : 369.

Bishop, E.J. and Grobler, J. (1971) Fmg. S. Afr. 47(2) : 21.

Blaxter, K.L., Wainman, F.W. and Wilson, R.S. (1961) Anim. Prod. 3 : 51.

Blaxter, K.L. and Wilson, R.S. (1962) Anim. Prod. 4 : 351.

Bloomfield, R.A., Garner, G.B. and Muhrer, M.E. (1960) J. Anim. Sci. 19 : 1248 (Abstr.).

Bloomfield, R.A., Welsch, C., Garner, G.B. and Muhrer, M.E. (1961) J. Anim. Sci. 20 : 926 (Abstr.).

Bloom, S., Jacobsen, N.L., Allen, R.S., McGillard, L.P. and Homeyer, P.G. (1959) J. Dairy Sci. 40 : 240.

Bolin, F.M. (1949) N. Dakota Agr. Exptl. Sta. Bi-monthly.

Boling, J.A., Bradley, N.W. and Lovell, D.R. (1971) J. Anim. Sci. 33 : 691.

Brannon, W.F., Reid, J.T. and Miller, J.I. (1954) J. Anim. Sci. 13 : 535.

Briggs, H.M., Gallup, W.D., Darlow, A.E., Stephens, D.E. and Kinney, C. (1947) J. Anim. Sci. 6 : 445.

Brisson, G.J. (1960) Proc. 8th Int. Grassland Cong. Reading : 435.

Buchanan, K.M. and Shone, D.K. (1966) J. S. Afr. Vet. Med. Assn. 37 : 159.

Burns, M.A. (1965) Queensland Agric. J. 91 : 12.

C.A.B. (1961) Commonwealth Bureau of Pasture and Field Crops Bull. 45 : 142.

Campbell, J.R., Howe, W.M., Martz, F.A. and Merilan, C.P. (1963) J. Dairy Sci. 48 : 131.

Campling, R.C., Freer, M. and Balch, C.C. (1962) Br. J. Nutr. 16 : 115.

Cavell, A.J. (1955) J. Sci. Fd. Agric. 6 : 479.

Chicco, G.F., Shultz, T.A., Rias, J., Plasse, D. and Burguera, M. (1971) J. Anim. Sci. 33 : 142.

Christian, K.R. and Coup, M.R. (1954) N.Z. J. Sci. Technol A 36 : 328.

Clanton, D.C. (1962) J. Anim. Sci. 21 : 216.

Clark, R., Oyaert, W. and Quinn, J.I. (1951) Onderstepoort J. Vet. Sci. 25 : 73.

Clark, R. and Quinn, J.I. (1951) Onderstepoort J. Vet. Res. 25 : 93.

Coombe, J.B. and Tribe, D.E. (1963) Aust. J. of Agric. Res. 14 : 70.

Coppock, C.E. (1970) Proc. Cornell. Nutr. Conf. p29.

Coppock, C.E., Everett, R.W. and Merrill, W.G. (1972) J. Dairy Sci. 55 : 245.

Corbett, J.L., Greenhalgh, J.F.D., Gwynn, D.E. and Walker, D. (1958) Br. J. Nutr. 12 : 266.

Corbett, J.L., Greenhalgh, J.F.D. and Macdonald, A.P. (1958) Nature Lond. 182 : 1014.

Corbett, J.L., Greenhalgh, J.F.D., Macdonald, A.P. and Florence, E. (1960) Br. J. Nutr. 14 : 289.

Coup, M.R. (1950) Proc. 10th Ann. Conf. N.Z. Soc. Anim. Prod. p43.

Coup, M.R. and Lancaster, R.J. (1952) N.Z. J. Sci. Technol A 34 : 347.

Cowlishaw, S.J. and Alder, F.E. (1963) J. Br. Grassland Soc. 18 : 328.

Crampton, E.W. and Lloyd, L.E. (1951) J. Nutr. 45 : 319.

Cresswell, E., Gill, J.C. and Fraser, C. (1968) Exptl. Husb. 17 : 20.

Curran, M.K., Leaver, J.D. and Weston, E.W. (1967) Anim. Prod. 9 : 561.

Cunha, T.J., Shirley, R.L., Chapman, H.L. Jr., Ammerman, C.B., Davis, W.G., Kirk, W.G. and Hentges, J.F.J. (1964) Fla. Agr. Sta. Bull. p683.

Davis, C.L., Byres, J.H. and Luber, L.E. (1958) J. Dairy. Sci. 41 : 152.

Dehority, B.A., Johnson, R.R., Bently, O.G. and Moxon, A.L. (1958) Arch. Biochem. Biophys. 78 : 15.

Deinum, B., Immink, H.J. and Deijs, W.B. (1962) Nutr. Abstr. Rev. 33 : 848.

Denton, D.S. (1967) Handbook of Physiology, Section 6 : Alimentary Canal Vol 1. Amer. Physiol. Soc., Washington DC.

Denton, D.A. (1969) Nutr. Abstr. and Rev. 39 : 4.

Denton, D.A. and Sabine, J.R. (1961) J. Physiol. Lond. 157 : 97.

Dinning, J.S., Briggs, H.M. and Gallup, W.D. (1949) J. Anim. Sci. 8 : 24.

Dinning, J.S., Briggs, H.M., Gallup, W.D., Orr, H.W. and Butler, R. (1948) Amer. J. Physiol. 153 : 41.

Ducker, M.J. and Fraser, J. (1975) Exptl. Husb. 29 : 113.

Edin, H., Kihlin, G. and Nordfedt, S. (1944) Lantbrukshögskolans Annaler 12 : 166.

Elliot, R.C. (1960) Rhodesia Agricultural Journal 57 : 412.

Ely, D.G., Little, C.O. and Spears, J.W. (1975) Distillers Feed Res. Council Proc. 30 : 43.

Faichney, G.J. (1968) Aust. J. Agric. Res. 19 : 813.

Fishwick, G., Fraser, J., Hemingway, R.G., Parkins, J.J. and Ritchie, N.S. (1974) J. agric. Sci. Camb. 82 : 427.

Fishwick, G., Fraser, J., Hemingway, R.G., Parkins, J.J. and Ritchie, N.S. (1977) J. agric. Sci. Camb. 88 : 143.

Fishwick, G. and Ritchie, N.S. (1977) J. agric. Sci. Camb. 88 : 71.

Fiske, C.H. and Subbarow, Y. (1925) J. Biol. Chem. 66 : 375.

Foot, J.Z. and Russel, A.J.F. (1973) Anim. Prod. 16 : 293.

Foot, J.Z., Russel, A.J.F., Maxwell, T.J. and Morris, P. (1973) Anim. Prod. 17 : 169.

Franklin, M.C., Briggs, P.K. and McClymont, G.L. (1955) J. of the Aust. Institute of Agric. Sci. 21 : 216.

Goodrick, R.D., Meiske, J.C. and Gharib, F.H. (1972) World Rev. Anim. Prod. 3 : 54.

Gordon, J.G. (1970) Proc. Nutr. Soc. 29 : 325.

Gordon, J.G. and Tribe, D.E. (1951) J. agric. Sci. Camb. 41 : 187.

Gosset, W.H., Perry, T.W., Mohler, M.T., Plumlee, M.P. and Beeson, W.M. (1962) J. Anim. Sci. 21 : 248.

Green, H.M. (1925) Physiol. Rev. 5 : 336.

Hardison, W.A., Engel, R.W., Linkous, W.N., Sweeney, H.C. and Graf, G.C. (1956) J. Nutr. 58 : 11.

Hardison, W.A. and Reid, J.T. (1953) J. Nutr. 51 : 35.

Hardison, W.A., Reid, J.T., Martin, C.M. and Woolfolk, P.G. (1954) J. Dairy Sci. 58 : 89.

Helmer, L.G., Bartley, E.E., Deyoe, C.W., Meyer, R.M. and Pfost, H.B. (1970) J. Dairy Sci. 53 : 330.

Hemingway, R.G. (1971) Proc. Nutr. Soc. 30 : 221

Hemingway, R.G., Inglis, J.S.S. and Ritchie, N.S. (1960) British Veterinary Association, Proc. of Conference on Hypomagnesaemic p58.

Hemingway, R.G. Macpherson, A., Duthie, A.K. and Brown, N.H. (1968) J. agric. Sci. Camb. 71 : 53.

Hemsley, J.A. and Moir, R.J. (1963) J. agric. Res. 14 : 509.

Hentes, J.F. Jr., Adams, J.R., Moore, J.E., Oltjen, R.R. (1967) J. Anim. Sci. 26 : 208 (Abstr.).

Hodgson, J. and Wilkinson, J.M. (1967) Anim. Prod. 9 : 365.

Holmes, W., Campling, R.C. and Joshi, N.D. (1972) Anim. Prod. 14 : 283.

Holmes, W. and Curran, M.K. (1967) Anim. Prod. 9 : 313.

Holmes, W., Jones, J.G.W. and Adeline, C. (1966) Anim. Prod. 8 : 47.

Holmes, W., Jones, J.G.W., Drake-Brokman, R.M. and White, N. (1965) Anim. Prod. 7 : 27.

Holter, J.B., Colovos, N.F., Davis, H.A. and Urban, W.E. Jr., (1968) J. Dairy Sci. 51 : 1243.

Horvath, D.J., Dozza, L., Kidder, H.E., Warren, J.E. Jr., Bhatt, B. and Croushore, W. (1967) Paper ores. North Atlantic Sect. Am. Soc. of Anim. Sci.

Hume, I.D. and Bird, P.R. (1970) Aust. J. Agric. Res. 21 : 283.

Hungate, R.E. (1966) The Rumen and its Microbes. New York and London : Academic Press.

Hutchinson, J.H. and Labby, D.H. (1962) J. Lab. Clin. Med. 60 : 170.

Ioset, R.M. (1969) Proc. Montana Nutrition Conference, Montana State University, Bozeman, Montana 20 : 26.

Itaya, K. and Ui, M. (1965) J. Lipid Res. 6 : 16.

Jackson, H.M., Kromann, R.P. and Ray, E.E. (1971) J. Anim. Sci. 33 : 872.

Jackson, P., Rook, J.A.F. and Towers, K.I. (1971) J. Dairy Res. 38 : 33.

Johnson, D.E., Dinusson, W.E. and Bolin, D.W. (1964) J. Anim. Sci. 23 : 499.

Jones, R.J. (1966) Austral. J. Exptl. Agric. Anim. Husb. 6 : 145.

Kameoka, K., Takahashi, S. and Morimoto, H. (1956) J. Dairy. Sci. 39 : 462.

Kane, E.A., Jacobsen, W.C., Ely, R.E. and Moore, L.A. (1953) J. Dairy Sci. 36 : 637.

Kane, E.A., Jacobsen, W.C. and Moore, L.A. (1952) J. Nutr. 47 : 211. 48 : 131.

Karalazes, A. and Swan, H. (1976) Feed energy sources for Livestock London Butterworths.

King, H.R., Embry, L.B. and Emerick, R.J. (1965) J. Anim. Sci. 26 : 1481 (Abstr.).

Kjeldahl, J. (1883) Analyt. Chem. 22 : 366.

Kromann, R.P. and Ray, E.E. (1967) J. Anim. Sci. 26 : 1379.

Lassiter, C.A., Grimes, R.M., Duncan, C.W. and Huffman, C.F. (1958) J. Dairy Sci. 41 : 281.

Lambourne, L.J. (1957) J. Agric. Sci. 48 : 273.

Lambourne, L.J. and Reardon, T.F. (1962) Aust. J. Agric. Res. 14 : 257.

Lancaster, R.J., Coup, M.R. and Percival, J.C. (1953) N.Z. J. Sci. Technol A 35 : 117.

Langlands, J.P. (1972) Anim. Prod. 14 : 317.

Langlands, J.P. and Corbett, J.L. (1964) J. Agric. Sci. 63 : 305.

Leaver, J.D., Campling, R.C. and Holmes, W. (1969) Anim. Prod. 11 : 11.

Lesch, S.F., Kemm, E.H. and Von Schalkwyk, A.P. (1967) Fmg. S. Afr. 43 (5) : 52.

Little, D.A. (1968) Proc. Aust. Soc. Anim. Prod. 7 : 376.

Longsdale, C.R., Poutiainen, E.K. and Taylor, J.C. (1971) Anim. Prod. 13 : 461.

Luttingh, H.C. (1961) J. Agric. Sci. 56 : 333.

Macrae, J.C. and Armstrong, D.G. (1969) Br. J. Nutr. 23 : 15.

Marsh, R., Campling, R.C. and Holmes, W. (1971) Anim. Prod. 13 : 441.

Meyer, J.H. and Weir, W.C. (1954) J. Anim. Sci. 13 : 443.

Meyer, J.H., Weir, W.C., Ittner, N.R. and Smith, J.D. (1955) J. Anim. Sci. 14 : 412.

Minson, D.J. and Pigden, W.J. (1961) J. Anim. Sci. 20 : 962 (Abstr.).

Ministry of Agriculture, Fisheries and Food, Department of Agriculture for Scotland, Department of Agriculture for Northern Ireland (1975) Bull.33. Energy allowances and Feeding Systems for Ruminants. London H.M.S.O.

Moore, J.H. (1959) Agric. Progr. 34 : 48.

Morris, J.G. (1958) Queensland J. of Agric. Sci. 15 : 161.

Moseley, G. and Jones, D.I.H. (1974) J. agric. Sci. Camb. 83 : 37.

Murdock, F.R., Hodgson, A.S., Miller, V.L. and Kimura, F. (1957) J. Dairy Sci. 40 : 618 (Abstr.).

Nelson, A.B., MacVicar, R.W., Archer, W. Jr., and Meiske, J.C. (1955) J. Anim. Sci. 14 : 825.

Oltjen, R.R., Slyter, L.L., Kozak, A.S. and Williams, E.E. Jr., (1968) J. Nutr. 94 : 193.

Oltjen, R.R., Waller, G.R., Nelson, A.B. and Tillman, A.D. (1963) J. Anim. Sci. 22 : 36.

Pamp, D.E., Goodrich, R.D. and Meiske, J.C. (1976) World Review of Animal Production Vol XII. 4.

Pearce, J. (1973) Agric. N. Ireland 48(8) : 288.

Pearce, J. and Raven, A.M. (1973) Rec. Agric. Res. 21 : 57.

Peart, J.N. (1967) J. agric. Sci. Camb. 68 : 365.

Pieterse, P.J.S. (1961) Fmg. S. Afr. 37(5) : 15.

Pieterse, P.J.S. and De Kock, J.P. (1962) Fmg. S. Afr. 39(4) : 84.

Pieterse, P.J.S., Lesch, S.F. and Von Schalkwyk, A.P. (1963) S. Afr. J. of Agric. Sci. 6 : 737.

Pigden, W.G. and Brisson, G.J. (1956) Canad. J. agric. Sci. 36 : 146.

Pistor, W.J., Nesbitt, J.C. and Cardon, B.P. (1950) 'Proceedings Book,' Am. Vet. Med. Assn., 87th Annual Meeting p154.

Playne, M.J. (1969) Aust. J. of Exptl. Agriculture and Animal Husbandry 9 : 192.

Potter, G.D., Little, C.O. and Mitchell, G.E. Jr., (1966) J. of Agricultural and Food Chemistry 14(6) : 647.

Putnam, P.A., Loosli, J.K. and Warner, R.G. (1958) J. Dairy. Sci. 41 : 1723.

Raymond, W.F., Kemp, C.D., Kemp, A.W., Harris, C.E. (1954) J. Br. Grassland Soc. 9 : 69.

Raymond, W.F. and Minson, D.J. (1955) J. Br. Grassland Soc. 10 : 282.

Reid, R.L. (1960) Analyst. 85 : 265.

Reyneke, J. (1971) S. Afr. J. Anim. Sci. 1 : 39.

Riggs, J.K., Colby, R.W., Sells, L.V. (1953) J. Anim. Sci. 12 : 379.

Ritchie, N.[illegible] and Hemingway, R.G. (1963) J. Sci. Fd. Agric. 14 : 162.

Roberts, M. (1967) Agriculture London 74 : 578.

Roberts, M. (1972) M.A.F.F., A.D.A.S. Pwllpeiran Exptl. Husb. Farm, Farm guide and report.

Russel, E.L., Hale, W.H. and Hubert, F. Jr. (1962) J. Anim. Sci. 21 : 523.

Sarif-Sarban, M. and Menke, K.H. (1970) Anim. Prod. 12 : 177.

Savage, D.A. and McIlvain, E.H. (1951) U.S.D.A. Southern Great Plains Field Station, Woodward, Oklohoma.

Scott, E.M. and Quint, E. (1946) J. Nutr. 32 : 113.

Scott, E.M., Verney, E.L. and Morissey, P.D. (1950) J. Nutr. 41 : 187.

Smith, A.M. and Reid, J.T. (1955) J. Dairy Sci. 38 : 515.

Smith, C.A. (1962) J. of Agric. Sci. 58 : 173.

Stern, E. (October, 1973) Livestock Farming 10(10) : 34.

Stevenson, A.E. (1962) N.Z. J. Agric. Res. 5 : 339.

Stevenson, A.E. and De Langen, H. (1960) N.Z. J. Agric. Res. 3 : 314.

Sutton, J.D. (1968) Br. J. Nutr. 22 : 689.

Sutton, J.D. (1969) Br. J. Nutr. 23 : 567.

Tait, A., Milne, J.A. and Russel, A.J.F. (1976) 27th Annual Meeting European Association for Animal Production.

Thomas, P.C. (1973) Proc. Nutr. Soc. 32 : 85.

Thompson, N.R., Graf, G.C., Eheart, J.F. and Holdaway, C.W. (1952) J. Dairy Sci. 35 : 1010.

Todd, J.R., Scally, W.C.P. and Ingram, J.M. (1966) Vet. Rec. 78 : 888.

Tollet, J.T., Swart, R.W., Ioset, R.M. and Templeton, J.A. (1969) J. Anim. Sci. 28 : 862 (Abstr.).

Troelsen, J.E. (1965) Anim. Prod. 7 : 239.

U.K. Fertiliser and Feedingstuffs Act (1976) (The Fertiliser and Feedingstuffs (Amendment) Regulations) H.M.S.O. London.

Unsworth, E.F., Lamb, C.S. and Armstrong, D.G. (1966) Proc. 9th Int. Congr. Anim. Prod. p73 (Abstr.).

Van Horn, H.H., Foreman, C.F. and Rodriguez, J.E. (1967) J. Dairy Sci. 50 : 709.

Van Niekerk, B.D.H., Basson, W.D. and Mulder, A.M. (1967) S. Afr. Tydskr. Landbouwet 10 : 687.

Weir, W.C. and Miller, R.F. (1953) J. Anim.Sci. 12 : 219.

Weir, W.C. and Torrell, D.T. (1953) J. Anim. Sci. 12 : 353.

Wilkinson, J.M. and Prescott, J.H.D. (1970) Anim Prod. 12 : 71.

Williams, C.H., David, D.F. and Iismaa, O. (1962) J. agric. Sci. Camb. 59 : 381.

Williams, N.M., Pearce, G.R., Delaney, M. and Tribe, D.E. (1959) Empire J. of Experimental Agriculture 27 : 107.