A STUDY INVESTIGATING THE NUTRITIONAL EFFECTS OF FEEDING BYPRODUCTS TO RUMINANT SPECIES DURING PERIODS OF PRODUCTION STRESS

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ABSTRACT

The studies undertaken for this thesis concerned the use of by-products as feeds for farm animals. Sheep and cattle were the species studied under different production systems.

The most important aspects of the studies were to determine the nutritive value of the by-products and to describe their relative values when used as feeds in a particular production system.

The General Introduction presents the reasons for this study. The continually increasing world population and concerns about the environment and efficiency of production have encouraged reduced wastage and recycling of products. Also the implications for human health are affected by the agricultural products available to the consumer. The methods of feed evaluation and the role of animal nutrition in the maintenance of health and prevention of disease are discussed.

Section I reviews the use of sugar beet by-products as animal feeds and describes the origins of the novel by-products under test. The experimental work, using sheep described the nutritive value of the by-products and the use of a limed molassed sugar beet pulp by-product as a feed for lactating ewes rearing twin lambs.

The nutritive value of the by-products was determined from digestibility studies. A pelleted, dried by-product containing molassed sugar beet pulp and brewers grains was shown to be a high protein (96.5g DCP/kg DM and high energy 11.6 MJ ME/kg DM feed. A limed molassed sugar beet pulp by-product, when fed to sheep, was shown to contain 60g DCP/kg DM, 11.1 MJ ME/kg DM and a high mineral content including calcium, 13.5, and phosphorus 1.1 (g/kg DM). The final by-product was the residual extract from sugar beet processing and was a highly digestible, medium energy (10.3 MJ ME) by-product.

Limed molassed sugar beet pulp provided an adequate supply of nutrients to ewes during lactation to achieve a mean lamb growth rate of 0.23 kg/day during the first six weeks, for twin lambs.

Section II described the origins of the novel by-product, under study, available to farmers within the whisky distilling regions of Scotland. Digestibility and degradability studies described wheat distillers SUPERGRAINS to be a high energy (13.6 MJ ME/kg DM feed with 142g RDP and 249g DCP/kg DM. A production trial using beef suckler cows identified the production benefits of feeding wheat distillers SUPERGRAINS as the sole protein source in comparison with a mixture of two proprietary compound feeds. The nutritional implications of feeding wheat distillers SUPERGRAINS over a long period (4 to 5 months) were exhibited by a loss of appetite and clinical and subclinical symptoms of hypomagnesaemia (mean blood magnesium concentration, 0.32 mmol l^{-1}).

A production trial using dairy cows identified the production benefits of feeding wheat distillers SUPERGRAINS as the concentrate source of a basal ration of silage (7 kg DM/day) in contrast to barley malt distillers grains over the total 24 weeks trial period the mean daily milk yield for all cows was 21.3 kg, 3.63% butterfat and 3.63% milk protein when wheat distillers SUPERGRAINS was the concentrate source. Over the same period, for the same cows the daily milk yield was 21.5 kg, 3.65% butterfat and 3.27% milk protein when malt distillers grains was the concentrate source. No adverse health problems were encountered and the use of fresh wheat distillers SUPERGRAINS as a feed for dairy cows was satisfactory.

Section III is concerned with the health of neonatal calves and lambs. The transfer of immunoglobulins was measured using serum immunoglobulin techniques. The calf study involved cows which had been fed different amounts of protein during pregnancy. The results indicated that for higher levels of dietary protein there was an increased colostral whey protein content and increased circulating calf immunoglobulins. This increase was shown to occur for total serum immunoglobulin and for the individual immunoglobulins.

The lamb study investigated the use of a proprietary ewe colostrum supplement (Imulam). From the results obtained, using a limited number of twin or triplet lambs, this supplementary product did not appear to provide any additional benefits to feeding either colostrum or milk substitute alone.

The experimental work conducted for this thesis aimed to be a direct reflection of intensive farming systems practised in Scotland under normal commercial constraints.

GENERAL INTRODUCTION

World Requirements

The world population in 1987 was 5024 million (United Nations, 1987). The food requirements for the world are dependant upon the combined agriculture industries of each nation. The developed nations have a well established productive agricultural industry. The U.K. industry has concentrated on intensification to increase outputs and the European Economic Commission (E.E.C.) and Common Agricultural Policy (C.A.P.) have been major influences on the current situation. Reid (1985) commented on the pressures being exerted on the U.K. industry in terms of budgetary and farm income demands, environmental, human health and animal welfare concerns, and the political influence of producers, consumers and international trade relations.

In recent years the quantity of output has been superseded by the quality of the products and efficiency of production. The Committee on Medical Aspects (COMA, 1984) and the National Advisory Committee on Nutrition Education, NACNE (1983) reports highlighted the effects of human dietary intake and the associated health implications. The livestock sector of the agriculture industry responded to these reports and changed production systems in order to produce products lower in saturated fat and reduced cholesterol content. The processing industries also modified the processing of milk and meat products in order to provide lean meat and skimmed milk products for consumers.

The current trends and concerns regarding environmental conservation and efficient utilisation of the worlds natural resources has improved techniques for recycling materials and the efficient utilisation of by-products. The refinement of raw materials from the agriculture industry has yielded a number of by-products which form a major component of the animal feeds sector. The use of waste products, after processing materials of animal and plant origin, as animal feeds has been practised over a long period of time. Analyses of the by-product compositions and increased knowledge of animal nutrition have improved the efficiency of feeding appropriate to specific animal enterprises.

Waste by-products as animal feeds

Food factory wastes (Theobald, 1986) can be cheap alternatives to cereal-based feeds but care must be taken to use waste feeds which will not adversely affect the animals health eg. by excess salt intakes, toxin intake, etc. The processing techniques for agricultural plants can significantly affect the nutritive value of the by-products, depending upon the plant species, processing procedure, species of animal fed and relative content of the by-product in the total diet (Burt, 1973). Boucque and Fiems (1988) reviewed the vegetable by-products of agro-industrial origin as feeds for livestock. The economic advantages of utilising a cheap waste by-product must not be at the expense of animal or human health. Those by-products of limited nutritional value may be combined with other materials or treated, with chemicals, radiation, heat, grinding etc., to produce a commodity of suitable nutritive value. Orskov (1980) described the use of by-products as animal feeds in terms of their digestibility and nitrogen content. An international collaboration has been developed (Haendler, 1980) to provide an information storage system on the value of by-products and wastes as animal feeds. Wilson (1980) notes that two important criterion for describing the value of by-product feeds are the digestibility and palatability.

Many by-products are no longer considered as waste, and have become an integral part of the production process, with separate systems for distribution, sales and marketing. The main examples would be sugar beet pulp by-products and brewery and distillers residues.

Health and Disease

When by-products are utilised in the animal feed industry their primary role is to provide the nutrients necessary for maintenance, growth and production of the animals. Once these demands have been fulfilled the prolonged health of the animals needs to be considered. Some by-product feeds may contribute to prophylactic health treatment by the presence of high mineral and vitamin levels.

The by-product feeds may be exposed to physical and chemical treatments to remove anti-nutritional factors and potential disease causing agents. The inclusion of enzymes, probiotics, growth enhancing agents and medicines in animal feeds are

controlled by The Medicines (Medicated Animal Feeding Stuffs) Regulations, 1985. The major health concerns of a nutritional nature are those of metabolic disorders. The vast amount of research and data published pertaining to specific nutrient quantities, form and availability includes the requirements (eg. Agricultural Research Council, ARC 1980) and recommended daily allowances (RDA) for growth, pregnancy and lactation (eg. Agricultural Advisory and Development Service, ADAS 1976, Ministry of Agriculture, Fisheries and Food, MAFF 1984). Particular attention to feed components is required for regions where essential elements are deficient in the soil, and where the associative effects of other nutrients present may cause the essential elements to become unavailable.

The associative nutritional effects can also be used in a beneficial way. Increased bicarbonate concentrations to improve fibre digestion and increased intake of polyunsaturated fatty acids (PUFA) to inhibit methane production, are two such examples.

The critical diseases of livestock, which result in death or significant economic loss, are predominantly opportunistic pathogens as viruses, bacteria, parasites and fungi. Effective disease control programmes are required to reduce the incidence and effects of diseases. As mentioned previously, the role of animal feedstuffs as prophylactic treatments are dependant upon the nature of the feed and the physiological action once ingested. Development of the mammalian immune system is dependant upon achieving a circulating immunoglobulin pool by passive and acquired transfer. Passive transfer, in farm species, is accomplished by the transfer of adequate amounts of maternal immunoglobulins present in colostrum. Other non-immune factors exist to prevent disease infection in the gut these include mucins, acidity regulators, enzymes, symbiotic microflora and the mechanical effects of peristalsis and evacuation. (Porter and Barratt, 1987) The local intestinal immunity is believed to play a major role in the immune system in addition to the circulating lymphocytes. Animal feeds can contribute to local intestinal immunity by the inclusion of enzymes, probiotics and organic acids in the feeds (Adams, 1988) of young animals. Artificial milk replacements and colostrum supplements have been manufactured to provide young livestock with an appropriate nutrient intake, in the absence of the mother.

The important zoonoses which may occur in the U.K. are tuberculosis, brucellosis, food poisoning organisms and anthrax. Effective disease eradication programmes in conjunction with health education and hygiene controls have significantly reduced the occurrence of these diseases, and for some total elimination. Agricultural practices have been criticised by the public. The scares in human health from food poisoning organisms such as Salmonella sp., Escherichia sp. and Campylobacter sp. The practice of feeding excrement to animals as a source of undigested nutrients has developed from a need to reduce the problems of pollution. Animal excreta has been effectively used as a feed source for pigs, poultry and cattle (Wilkinson, 1980). The increasing evidence of poultry meat and eggs contamination with enteric bacteria has prohibited the use of animal excreta as an animal food source. The Animal Health Act (1981) combined the Disease of Animals Acts 1935, 1950, 1975 as described by Watson (1980) for veterinary and by-product feeds legislation. Since the problems encountered with Salmonella sp. from feeding animal excreta amendments have been made to this Act. (The Processed Animal Protein Order, 1989). Another purpose of this amendment was to reduce the incidence of bovine spongiform encephalopathy by prohibiting the use of brain and spinal column tissues as animal feed sources.

Feed Evaluation

The nutritional value of a feed is described primarily in terms of its composition and subsequently as the quantity of nutrient from the feed which is digested. Some of the earliest work (Armsby, 1917) in digestibility studies was undertaken over 70 years ago. The advances of science and refinement of techniques has considerably developed the practical application of results from digestibility experiments.

Once the proximate composition and digestibility values have been determined the areas of investigation are directed to examine the fate of digested nutrients and the efficiency with which they are utilised. The major factors affecting digestion are the chemical structure of the feed, physiological state of the body and the associative digestion effects. Schneider and Flatt (1975) define the principles and practice for accurate determination of digestibility values. The physical form of ruminant feeds directly affects the amount of saliva produced, the subsequent rumen pH and volatile fatty acid (VFA) production.

The first stage in feed evaluation is the determination of proximate composition which provides a coarse description of the feed. The traditional proximate analysis is now being superseded to described components in greater detail. Crude protein fed to non-ruminant species is increasingly being described in terms of the amino acid composition. For ruminants the crude protein content of a feed has more recently been described as the rumen degradable protein (RDP) and rumen undegradable protein (UDP). Crude fibre, because of the variable nature, is increasingly described as the acid detergent fibre fraction or neutral detergent fibre fraction which defines the cell wall content. The oil content of feeds has been described as the ether extractable component, but modern analysis also describes the essential fatty acid and polyunsaturated fatty acid composition of the feed. The ash fraction describes the total mineral content of the feed but does provide any information concerning the form in which the minerals are present or the relative concentrations of macro- and trace elements. The gross energy value of a feed does not identify the amount of energy which can effectively be used by the animal.

Determination of the metabolisable energy (ME) of the feed can be determined using animals in respiration chambers, but alternatives to this expensive technique are being investigated. The ultimate test for determining the validity of the value of a feed is by biological evaluation in the target species. The relative value of a feed is dependant upon the species and method of production system in which it is used (Blaxter, 1977). Lactational responses to nutrient intake are less variable than the responses of growing animals.

Digestibility experiments are frequently performed using more than one feed, in order to provide an appropriate dietary intake, and all calculations are based upon the assumption that digestibility is unaffected by other feeds, and the physiological state of the animal. The Department of Agriculture and Fisheries, Scotland, (DAFS, 1975) describes the procedures used for measurement of urinary energy, faecal energy and methane energy in sheep, in order to derive digestible and metabolisable energy (ME) values of a feed. DAFS (1975) also proposed the use of linear and non-linear models for calculating ME when two feed sources are fed.

Apart from feed composition digestibility is also affected by the rate of passage of digesta, particle size, rate of rumination Welch (1982) and the volume of water intake (Little and Shaw, 1978).

Feed evaluation using production trials is determined for a target species or production system. The physiological interactions, particularly for the growing, pregnant, and/or lactating dairy cow, may disguise the direct influences of feeding a particular diet. Environmental factors are also known to affect production, eg. daylight length, temperature, housing and stocking rate, and it is therefore important to accurately record all details concerned with the production trial.

Long term feeding of a product is needed to fully describe its value, particularly when concerned with associated animal husbandry factors such as conception rates, calving indices, susceptibility to disease, age at weaning etc.

Detailed studies have been performed to describe the rumen microbial ecosystem (Hungate, 1970) in relation to protozoal populations of cattle fed molasses (Foulkes and Leng, 1988) and particularly in relation to bacteria species and volatile fatty acid production. Recent advances in biotechnology may provide the potential for altering the microbial populations in order to increase feed digestion, microbial cell protein and VFA production (Hespell, 1987) and reduce methanogenesis.

A wide variety of by-product materials, home-produced and imported, are incorporated into animal feeds (Boucque and Fiems, 1988). Each particular by-product possesses specific characteristics which determine its usefulness as an animal feed. Sugar beet pulp by-products are a good source of digestible energy but contain crude protein of a low digestibility. These by-products from sugar production are deficient in phosphorus relative to cereal products. By-products from the brewing and distilling industry are well recognized for their high crude protein content, although they are unsuitable as sole feed sources due to very low calcium, magnesium, potassium and sodium levels.

Large scale animal feed manufacturers using least cost ration formulations frequently use materials of low nutritive value, such as extracted coffee residues

which are low in energy and protein and act as a diuretic. New methods of improving the nutritive value of cheap, readily available materials such as straw are continually being investigated eg. Hydroxide treated straw.

The most important sources of by-product feeds in the U.K. are the sugar industry and brewing and distilling industries. The processing techniques are highly efficient and produce by-products of relatively constant composition unlike the commercially formulated feeds which vary considerably in the source of basic nutrients.

This study was carried out to assess the nutritional contribution of a variety of novel by-products from the sugar industry and the distilling industry, either as sole feeds or as components of a diet.

SECTION I

SUGAR BEET BY-PRODUCTS AS ANIMAL FEEDS FOR RUMINANTS

BACKGROUND REVIEW

History of sugar beet production in the U.K.

Successful sugar beet processing factories were established in the early 1900s, after earlier unsuccessful attempts during the late 1800s. In 1936 the British Sugar Corporation was formed, by an Act of Parliament. Farmers had a major interest in the company and its policies and eighteen factories were built nationwide during the development of the U.K. sugar industry. In 1971 acquisition by Berisford International resulted in a change of name to British Sugar plc who currently hold a monopoly on U.K. sugar beet production. Approximately 12,000 registered U.K. growers farm 201,000 ha and produce, on average, 6 tonnes sugar/ha, which meets 50% of the annual U.K. requirement of 2.2 million tonnes. The remainder is produced from sugar cane, a tropical crop with 2.5 year growth season.

Prior to Britain joining the E.E.C. two-thirds of British sugar was imported under the Commonwealth Sugar Agreement. The Rome Convention and C.A.P. in 1975 produced new agreements with the African and Caribbean countries and Britain was compelled to increase self-sufficiency in sugar.

Sugar beet, Beta vulgaris family Chenopodiaceae, is a typical xerophyte, growing best in light, sandy soils free from large stones which impair root growth. The large foliage canopy above the soil surface utilises sunlight energy for energy storage, as sucrose, in the vascular tissues. Sugar beet is cold tolerant and has a long growing season. The success of the crop is dependent upon sun and high rainfall, the harvest begins in September and starts the traditional "campaign". The main growing areas are in East England and 13 factories process the sugar beet from producers holding contracts. The prices are based upon 16% FM sugar content, early and late delivery bonuses, yield and transport allowances (English, 1984). Most beet is mechanically harvested and the tops are removed. The tops can be wilted and fed to livestock, remembering to introduce the feed gradually, minimise soil contamination which affects digestibility and provide extra calcium as a high

oxalate content can cause digestive problems. In Europe, but not in Britain, sugar beet tops are frequently used to make silage.

Sugar beet processing

At the factory sugar beet loads are inspected for soil contamination, top tare (the crowns, hypocotyl, should be intact as this contains a high mineral concentration), core samples are removed to test for quality and the load weighed.

The beet are conveyed along fast flowing water for washing. The beet are then sliced into V shaped strips (cossettes) approximately 2mm wide to facilitate sugar extraction. The cossettes are submerged in water, at 72^{o}C, in a rotating drum and sugar diffuses out of the beet into the water. Flanges in the diffuser drum direct extracted beet to the exit, where solid material is separated from the liquid. Calcium oxide (quicklime) is added to the sugary liquid to precipitate impurities and filtered. The resultant juice is concentrated by evaporation and then boiled, under reduced pressure, to produce a supersaturated solution. Crystallisation is initiated by the addition of sugar seed crystals, from previous batches, and the subsequent crystals formed are washed, dried, graded and packaged for sale. During the washing procedure centrifugation of the sugar crystals separates a liquid which is reconcentrated to form molasses.

Formation of by-products

Extracted beet contains 5-7% dry matter and by passing the wet pulp through large screw presses the dry matter content is increased to 15-18%, the majority of this pressed pulp is then dried. Molasses may be added as the pulp leaves the presses and mixed by a series of angers. Pressed pulp (with or without molasses inclusion) is dried in large rotating cylinders and a fan draws hot gases (1000^{o}C) from the furnace through the drier. The high moisture content of pulp prevents actual pulp temperature from rising much above 100^{o}C. The temperature levels are closely regulated because even short periods of temperature in excess of 100^{o}C may affect protein digestibility of the pulp.

Pressed pulp (generally without molasses) is frequently sold in bulk for direct feeding on local farms when the production exceeds the drying capacity. The by-

products which are produced from sugar beet processing are wet pulp, pressed pulp with or without molasses addition, dried pulp, with or without molasses, in shredded or pellet form and molasses alone. The increase in sugar production since 1970 to 105m tonnes has also increased molasses production, of which 13m tonnes is beet molasses (Holderness-Roddam, 1989).

Traditionally, molassed sugar beet pulp has been used alone or in farm-mixed concentrates as animal feeds. The molasses inclusion rate is normally 40% (about 20% sucrose) which makes the feed material highly palatable. During the 1960s and 1970s calcined magnesite (60g in 2kg) was included as part of the production process. In the 1970s a product containing urea, minerals, trace elements and vitamins, with 17% crude protein, was commercially available. Recently these and other factory mixed products have been discontinued and more of the unmolassed pulp goes directly to the compound feed industry. In Europe, molasses is infrequently included, and the majority of the pulp is used in compound feeds.

Sugar beet by-products as animal feeds

Lofgreen, Bath and Young (1962) evaluated the net energy (NE) of sugar beet by-products, fed to growing steers, using barley as a reference standard. The NE values obtained for plain dried pulp, 83, MSBP, 74, and molasses, 92, when expressed as a percentage of barley, indicated the potential value of sugar beet by-products as energy feed sources in ruminant diets. Lofgreen and Garrett (1968) calculated NE for maintenance to be 94% that of barley and NE for growth to be 95% for that of barley. Other authors (Hemingway et al., 1976) have reported the effective use of MSBP and urea as a source of protein although the feed conversion efficiency was inferior to diets containing barley. MSBP has been shown to be a feed source, of equivalent value to barley for lactating dairy cows eg. (Castle, 1972) and no difference was observed in the molar proportions of rumen volatile fatty acids.

Development of a fortified sugar beet pulp, by Parkins, Hemingway and Ritchie (1974), for feeding to lactating dairy cows, produced a concentrate feed which met the nutrient requirements of lactating cows. This product was commercially available and contains 3% urea, 40% molasses and 3% dicalcium phosphate. Other

fortified sugar beet pulp feeds have produced a complete ration containing elevated levels of magnesium.

More recent work by Parkins, Hemingway and Fraser (1986) and Hemingway, Parkins and Fraser (1986) has described the relative value of undried pressed pulp (UPP), MSBP and unmolassed sugar beet pulp (USBP) as feeds for dairy cows. The increasing costs of drying, cubing and packaging may induce some produces to consider using fresh pulp. The UPP had a similar palatability to MSBP but the bulk nature of the feed tended to reduce the voluntary feed intake within a set period of time. There was an increased milk yield for cows fed UPP, but a reduction in milk fat concentration. The palatability of USBP was reduced due to the absence of molasses, but similar milk fat and protein yields were obtained. These workers indicated the use of USBP as a good source of rumen undegradable protein (UDP). Feeding lactating dairy cows on silage based diets and MSBP was reported by Hemingway, Parkins and Fraser (1986b) to reduce milk yield but increase milk fat concentration relative to feeding unmolassed pressed pulp.

The consistent and much quoted nutritive value of MSBP, 12.5 MJ ME/kg DM and 80g DCP/kg DM (DAFS, 1978; MAFF, 1986), may allow farm-mixed compound feeds to be formulated containing up to 70% MSBP to achieve equivalent levels of production as commercial concentrate feeds. (Fishwick and Hemingway, 1987). The advantages of these sugar beet by-products are the consistent composition and nutritive values when compared to compound feeds (formulated as least cost rations) of variable ingredient composition and undeclared ME, DCP and RDP components. Sugar beet by-products are also widely used in sheep production systems (Ducker, Fraser and Hemingway, 1976) as a source of energy and protein. The inclusion of urea in diets containing MSBP, when fed to ewes during pregnancy and lactation, showed an improved lamb birthweight and growth rate (Hemingway and Parkins, 1972) relative to that for ewes fed MSBP without urea. Parkins, Fraser, Ritchie and Hemingway (1974) reported that there were improved lamb growth rates when ewes were given an increased DCP intake, as urea, added to MSBP during pregnancy and lactation.

Sugar beet pulp has been demonstrated to be superior energy source than maize in diets for fattening lambs. (Bhattacharya, Khan and Uwayjan, 1975).

Molasses, a sugar beet by-product, is normally incorporated onto other by-products before use as an animal feedstuff. Some cane molasses is used in the U.K., due to the demand being in excess of that supplied by beet molasses. Molasses from sugar cane contains less protein than sugar beet molasses. The residue following biochemical processes using molasses as the substrate is known as condensed molasses solubles (CMS). This residue has been shown (Ronning and Bath, 1962) to have an equivalent value to normal molasses when added to sugar beet pulp and fed to dairy cows. Molasses or CMS can be combined with lignosulphates, to improve pellet formation and can form a high energy, high protein liquid product when mixed with a by-product from the dairy manufacturing industry (Mayes, 1989). These alternative by-products are not as palatable as either cane or sugar beet molasses.

Beet molasses has been used in rations for finishing dairy bullocks (Garrett, 1989) with the inclusion of monensin which counteracts the deleterious effects of feeding high levels of molasses, principally bloat. Beet molasses improved the digestibility of crude protein and organic matter and the monensin increased the proportions of propionate produced in the rumen. When these feed substances were fed together to bullocks receiving a diet containing hay and barley, there was an improved energetic efficiency of rumen digestion. Molasses inclusion rates in compound rations for cattle (8%) and pigs (4-6%) provides a constant demand for this highly fermentable sugar beet by-product. (MAFF, 1989)

Alternative agricultural and nutritional uses for sugar beet by-products.

Research and development work by British Sugar plc using sugar beet by-products has resulted in a source of fibre suitable for inclusion into human diets. (Hillier, 1990) The advances in food technology have enabled techniques to be employed for extracting food additives from sugar beet by-products and the potential exists, using gene transfer techniques, for creating specialty chemicals to be produced within sugar beet tissue.

The manufacture of alcohol and biochemicals, such as monosodium glutamate, citric acid and yeasts can utilise molasses as the major fermentation substrate (Karalazos and Swan, 1976).

Molassed sugar beet pulp has been used, increasingly as a grass silage absorbent, mixed in entirely or distributed in layers. The high energy value of sugar beet pulp including molasses raises the total sugar content and promotes a good fermentation. The absorbent characteristic of the pulp allows an increase of 3 to 4 times its own weight and retains the highly nutritious effluent and prevents the potential pollutant effect. (Brown, 1989).

Alternative sugar beet processing techniques which generate novel by-products for animal feeds.

1) Limed molassed sugar beet pulp (LMSBP)

The economic advantages of lime, $Ca(OH)_2$, addition during the sugar extraction process are the reduced costs associated with drying sugar beet pulp, and the utilisation of existing equipment and factory operations.

Randall, Edwards and Camirand (1988) described in detail the technical procedures for liming sugar beet during sugar extraction. Essentially, there are three methods for using lime in the sugar extraction process: -

a) Addition of lime to fresh sugar beet tissue, in cossette form, prior to diffusion.
b) Addition of lime to heated cossettes after diffusion, prior to pressing.
c) Addition of calcium monosaccharate solution to cossettes prior to diffusion.

The addition of lime, as calcium hydroxide, is the most important process when the sugar beet tissue is used as freshly sliced cossettes. Sugar beet tissue consists mainly of pectic substances (alpha-D-galacturonic acid derivatives). The alkaline conditions prevailing when the beet is mixed with lime, at ambient temperatures, induces demethylation and deactylation of pectins which protects the integrity of the pectins from degradation when the beet pulp is heated in the diffuser. The pectins are retained within the pulp and subsequently increase the dry matter content of the pulp, used for animal feeds. The calcium content of the pulp is significantly increased which has beneficial implications for use of this pulp as a feed for

lactating animals, particularly dairy cows, although the phosphorus imbalance occurring would need to be adjusted during feed formulation. The other potential advantages of liming sugar beet are the decreased quantities of non-sugars occurring in a clear extracted sugar juice and reduced requirements for biocides necessary for controlling microbiological activity in the diffuser. Cossette liming may facilitate the direct expression of juice from beet tissue by pressing and eliminate the conventional diffuser. This can result in reduced drying costs.

Also, the increasing use of beet pulp as a source of dietary fibre in human diets may benefit from this processing technique. Recent indications (Slattery, Sorenson and Ford, 1988) suggest that calcium pectate may reduce the incidence of colon cancer normally associated with a high dietary fibre intake.

2) Extruded extract (EXT)

This particular sugar beet by-product is formed during the extraction of sugar and the extraction of a second commercially viable biochemical. The by-product originates from conventional factory diffused sugar beet. The extruded sugar beet pulp is further extracted by the addition of chemicals to produce a human feed additive. The pulp residue is rotary and hot-box dried to form the final extracted by-product (EXT).

The by-product (EXT) was expected to contain a high proportion of insoluble fibre and the use of EXT as a ruminant feed is unknown.

3) Mixed by-product formed from molassed sugar beet pulp and dried brewers grains (M/DBG).

This novel by-product originates from two different processes, from the brewing industry and sugar beet industry. A standard conventional molassed sugar beet pulp (MSBP) and wet brewers grains (BG) were mixed and dried to form a pelleted by-product (M/DBG). M/DBG is anticipated to be of greater value as an animal feed than either of the single by-products fed alone, with an expected crude protein content of about 150g/kg DM.

EXPERIMENT 1 DETERMINATION OF THE NUTRITIONAL VALUE OF SOME NOVEL SUGAR BEET BY-PRODUCTS

INTRODUCTION

The experiment was designed to assess the nutritional value of four different by-product feeds from the sugar beet processing industry as feeds for ruminant animals. One feed was a mixed dried product containing a sugar beet by-product and a brewery by-product. The three other feeds were all by-products produced, from processing sugar beet. Preliminary studies on a limed molassed sugar beet pulp by-product had been performed by Abubakar (1989). A normal molassed sugar beet pulp was used in the study as a standard feed by-product for comparison with the novel feed by-products. Laboratory analyses were performed in order to describe the feeds in terms of proximate composition, gross energy value and macroelement content.

In digestibility trials using molassed sugar beet products, containing up to 40% molasses, it is not possible to feed these products alone because of the marked tendency for the sheep to produce soft unpelleted faeces. Apart from the resulting problem of the accurate assessment of faecal dry matter output there would also be uncertainty over the effect of a degree of scouring on the digestibility of the feed.

Accordingly, it is necessary to feed these highly fermentable by-products with another feed, such as dried grass which will reduce the associated effects. If the digestibility of the dried grass nuts is known with accuracy, when fed alone, then when an additional feed is fed its digestibility can be determined by difference. It was assumed that the digestibility characteristics of the dried grass were not affected.

Experiment 1(a) describes the assessment of the dried grass nuts using in vivo methods.

Digestibility trials were performed in vivo in Experiment 1(b), wether sheep in metabolism crates, to determine the apparent digestibility of nutrients in the feeds.

Rumen degradability studies (Experiment 1(c)) were performed in vivo using the nylon bag technique in rumen fistulated cows, to determine the intraruminal degradation capacity for each feed.

The use of the artificial fibre bag technique (Mehrez and Orskov, 1977) has been used to report the change in protein value following rumen incubation (Smith and Mohammed, 1977) and the extent of protein degradation in basal feeds using sheep (Orskov and Mehrez, 1977). Mathers, Horton and Miller (1977) obtained comparable results when using the polyester bag technique in sheep, for estimating ruminal protein degradation as were obtained using cannulae inserted immediately post-rumen.

Experiment 1(a) Determination of the apparent digestibility of dried grass nuts

MATERIALS AND METHODS

Animals and Management

The sheep, Texel cross wether lambs of similar age (10 months) and liveweight (44 kg) were examined and confirmed to be in good condition and free from disease. They were housed in metabolism crates for the duration of the experiment. (Duthie, 1959)

Each sheep had the wool clipped from around the hind quarters and a leather harness and rubber faecal collection bag was attached in order to determine total faecal output. The sheep were fed twice daily and had free access to drinking water at all times. A pre-trial period of ten days, when the diets were introduced gradually to the sheep, allowed time for rumen adaptation to the diets.

The trial period lasted 14 days, during which time faecal collection bags were emptied daily and any feed refusals recorded. Total faecal outputs for each sheep were collected during the last seven days of the trial and bulked, from which representative subsamples were removed for analysis (Appendix 2).

The housing environment was suitable for this experiment. The metabolism crates were positioned in order to provide the sheep with visible access to other sheep.

The temperature was maintained between $+1^{o}C$ and $+10^{o}C$, and there was an adequate air flow. The first seven days of the trial allowed the sheep to become acclimatised to the environment and experimental procedures.

Feeds and feeding

A large uniform consignment of dried grass nuts was obtained and stored in 25 kg sacks. A good quality grass was chosen in order that the digestibility of the dried grass would be unlikely to be affected by the subsequent addition of other feeds.

The diet of dried grass nuts was accurately weighed ($\pm$ 1.0g) in advance, for each daily feed of 1.0 kg fresh matter/head/day.

Feed sampling

Representative samples of feed were taken during the 14 day trial and dried at $95^{o}C$ for 48 hours, or until a constant weight was reached. The dried feed samples were milled through a 0.8mm screen in a laboratory mill (Christy and Norris, 8-inch hammer mill) and subsamples removed for determination of proximate composition (Appendix 1).

RESULTS

Calculation

$$\text{Apparent digestibility} = \frac{\text{Total [nutrient]}^{*}\text{ intake - Total faecal [nutrient] output}}{\text{Total [nutrient] intake}}$$

1.0kg FM intake dried grass nuts (920g DM)

Daily faecal output 280g DM

$$\text{Apparent digestibility} = \frac{920g - 280g}{920g}$$

$$= 0.6957 \text{ dry matter digestibility coefficient.}$$

*[ ] applies to dry matter, crude protein, crude fibre, organic matter and gross energy.

Table 1.1. describes the proximate composition of the dried grass nuts. It was a high quality dried grass, containing 25% crude protein and 90% organic matter. The crude fibre content (22%) was high and the gross energy value was high (18.4 MJ) despite a low oil content (4%).

The dried grass was a palatable feed which all the sheep ate and no residues were recorded. There were no problems encountered with faecal collections and digestibility calculations. Table 1.2 describes the apparent digestibility of dried grass nuts in terms of digestibility coefficients. The very low standard error values indicated that the constant apparent digestibility coefficients could be accepted with confidence.

Table 1.3 describes the nutritive value of the dried grass nuts, determined using quoted (MAFF, 1984) prediction equations. It contains a high digestible crude protein content (177g/kg DM) and adequate metabolisable energy value 9.8 MJ. These values and apparent digestibility coefficients determined will be referred to later for the calculation of the digestibility of the sugar beet by-products (Experiment 1(b)) and distillery by-products (Experiment 3).

Table 1.1

Proximate composition of dried grass nuts (g/kg)

Nutrient	n	$\bar{x}$	sd	se
Dry matter (DM)	3	920	10.12	5.84
DRY MATTER COMPOSITION				
Crude protein (CP)	4	250	6.59	3.30
Crude fibre (CF)	4	223	4.48	2.24
Ash	4	90	0.60	0.30
Ether extract (EE)	4	41	7.48	3.74
Organic matter (OM)	4	910	0.60	0.30
Calcium	4	6.10	0.13	0.06
Phosporus	4	3.21	0.15	0.07
Gross energy (GE) MJ/kg DM	4	18.4	0.06	0.03

Table 1.2

Apparent digestibility coefficients of dried grass nuts

Nutrient	n	$\bar{x}$	sd	se
Dry matter (DM)	18	0.69	0.015	0.003
Organic matter (OM)	18	0.69	0.016	0.004
Crude protein (CP)	18	0.71	0.015	0.003
Crude fibre (CF)	18	0.65	0.034	0.008
Gross energy (GE) MJ/kg DM	18	0.66	0.014	0.003

Table 1.3

Nutritive values determined for dried grass nuts (/kg DM)

Digestible Crude Protein (DCP)	177 g
Digestible Organic Matter of the dry matter (DOMD)	631 g
Digestible Energy (DE)	12.10 MJ
Metabolisable Energy (ME) (DOMD% X 0.155)	9.78 MJ
ME (DE X 0.81)	9.80 MJ
ME (DE X 0.81 + 1.018)	10.82 MJ

Calculations for determination of metabolisable energy obtained from MAFF/ADAS Reference Book 433 (1984)

Experiment 1(b) Determination of the apparent digestibility of sugar beet by-products.

MATERIALS AND METHODS

Experiment 1(b) describes in detail the experimental procedure for digestibility determinations using sheep in metabolism crates.

Animals and Management

Groups of six sheep, of similar age (10 months) and liveweight (45 kg) were randomly allocated to each of the diets given.

Feeds and Feeding

Four feeds were evaluated in the trial. Three were by-products from the sugar beet processing, a normal standard cubed molassed sugar beet pulp, ex-King's Lynn

(MSBP), cubed limed molassed sugar beet pulp (LMSBP) and an extruded sugar beet extract ex-Cantley/Winkworth (EXT). The fourth feed was a mixed cube containing molassed sugar beet pulp and dried brewers grains (M/DBG).

The various by-products under investigation were fed in a mixed ration, containing dried grass nuts (DGN). The digestibility of which had previously been assessed using eighteen wether sheep. (Experiment 1.a) The proportions of dried grass nuts to be included in each dietary ration were determined in preliminary trials as being appropriate in terms of both palatability and faecal consistency.

Each treatment ration was accurately weighted ($\pm$1g) out for one day, for each individual sheep, to be given in two, approximately half, feeds. It was anticipated that each treatment ration, described in Table 1.4, would provide approximately 11.0 MJ of metabolisable energy (ME) which is considerably more than the quoted value (MAFF 1984) for growing sheep of this liveweight. Five dietary rations were actually fed, because one feed byproduct (M/DBG) was fed alone in addition to being fed as a mixture containing DGN.

Table 1.4

Daily fresh matter (FM) intake (kg) of each diets and the mean liveweight (kg) for each group of sheep.

DIET	BY-PRODUCT		DRIED GRASS NUTS	LIVEWEIGHT
1	MSBP	0.5	0.5	41.7
2	M/DBG	0.5	0.5	43.6
3	M/DBG	1.0	0	42.9
4	EXTRACT	0.8	0.2	42.4
5	LMSBP	0.6	0.6	52.6

RESULTS

Calculation

i) Single Product

$$\text{Apparent digestibility} = \frac{\text{Total [nutrient]}^{*}\text{ Feed Intake - Total [nutrient] Faecal Output}}{\text{Total [nutrient] feed intake}}$$

Total by-product intake (883g DM) $\quad \frac{883 - 240}{883}$
Daily faecal output 240g DM

Apparent digestibility coefficient = 0.73 for dry matter

*[ ] for dry matter, crude protein, crude fibre, organic matter

ii) Mixed products

$$\text{Apparent digestibility} = \text{By-product [nutrient] intake} - \left[\text{Total [nutrient] faecal output} - (\text{1-apparent digestibility coefficient for DGN}) \times \text{DGN [nutrient] intake}\right]$$

By-product Intake = 442g DM

DGN Intake = 460g DM

Total faecal output = 260g DM

Apparent digestibility coefficient for DGN = 0.6927

Apparent digestibility of by-product = 422 - [260-(1-0.6927) x 460]

Apparent digestibility of by-product = 0.73 for dry matter

The proximate composition of the feeds, determined from representative subsamples taken during the trial, are shown in Table 1.5. The mean values obtained were consistent, with little deviation from the mean value. Using these values and the values determined for faecal composition the apparent digestibility of individual nutrients within the feeds was determined. The results from sheep given diets 1 to 4 can be directly compared, as the groups of six sheep were balanced according to liveweight, and the trials were run concurrently in the same building.

Table 1.5 Mean composition (g/kg) of by-product feeds, and dried grass nuts.

	MSBP	LMSBP	M/DBG	EXT	DGN
DM	873	871	883	914	898
DM Composition					
CP	108	102	144	115	249
CF	146	167	129	257	225
MADF	173	188	ND	ND	ND
EE	4.4	5	23	3.6	43
Ash	96	89	81	69	91
NFE	637	637	623	555	392
OM	904	911	919	931	909
Ca	12.07	13.53	6.39	16.3	6.47
P	0.85	1.07	2.32	1.3	3.08
GE (MJ)	16.5	16.4	17.8	16.5	18.3

ND = not determined

Table 1.6 Mean apparent digestibility coefficients determined for each feed

	MSBP		M/DBG		M/DGB (Fed alone)		EXT		LMSBP	
Nutrient	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM
DM	0.824	0.013	0.738	0.018	0.738	0.008	0.740	0.035	0.80	0.018
OM	0.851	0.014	0.745	0.020	0.750	0.008	0.791	0.034	0.84	0.017
CP	0.566	0.030	0.627	0.018	0.670	0.031	0.331	0.025	0.59	0.008
CF	0.740	0.041	0.550	0.037	0.586	0.013	0.774	0.042	0.649	0.054
GE	0.822	0.013	0.733	0.013	0.736	0.010	0.752	0.039	0.80	0.017

Nutrient value of each Feed					
DCP g/kg DM	61.1	90.3	96.5	38.1	60
DE MJ/kg DM	13.6	13.0	13.1	12.4	13.1
DOMD g/kg DM	769	685	689	736	765

The mean apparent digestibility coefficients for each diet are shown in Table 1.6. Normal MSBP was shown to be the most digestible feed in terms of dry matter (82%), organic matter (85%) and gross energy (82%) digestibility. The novel sugar beet by-product, EXT, showed a very low apparent crude protein digestibility coefficient of 33%.

EXT appeared to contain a highly digestible (77%) crude fibre fraction and contained the least amount of apparently digestible energy of all the feeds examined.

Diets 2 and 3 both containing M/DBG showed almost identical apparent digestibility coefficients. The diet containing M/DBG alone showed very small standard errors from the mean digestibility coefficients and these values were considered to be the most accurate. The crude protein apparently digestible component was 67% and the apparently digestible crude fibre content only 59%.

Using the in vivo determined D.E. values calculations from prediction equations were used to determine the ME value of the feeds.

The Rowett Research Institute (RRI), Feed Evaluation Unit (FEU) (DAFS, 1978) examined four shredded and four pelleted molassed sugar beet pulp feeds, and concluded that ME values of molassed pulp feeds could be estimated using the identity: - ME = DE X 0.845 or ME = DOMD% X 0.139. From these prediction equations the ME value (MJ/kg DM) for MSBP was calculated to be 11.5 and 10.7 and the calculated ME value (MJ/kg DM) for LMSBP was determined to be 11.1 and 10.6 MJ/kg DM respectively.

DAFS (1981) contained a study of 23 compound feeds which may be appropriate to use as comparisons for EXT, an unmolassed by-product. The prediction equation for determination of ME (MJ/kg DM) was given as ME = DE X 0.832. The ME value calculated for EXT is 10.3 MJ/kg DM. The mixed product M/DBG contained unknown proportions of MSBP and brewers grains, but for the purpose of this study it was assumed that they were present as equal parts. DAFS (1984) determined urinary and methane energy losses from sheep given brewers grains to

be 8.05% of the G.E. and the identity ME = DE X 0.9195 is appropriate for brewers grains. By combining this equation and that determined for MSBP (DAFS, 1978) ME = DE X 0.845 an estimation of ME for M/DBG could be made, from ME = DE X 0.882, as 11.6 MJ/kg DM.

Experiment 1(c) Rumen degradability study

MATERIALS AND METHODS

Four feed by-products were examined in this experiment, vis. molassed sugar beet pulp (MSBP), limed molassed sugar beet pulp (LMSBP), MSBP/dried brewers grain mixture (M/DBG) and extruded sugar beet pulp extract (EXT).

Feeds and incubation sacs

Each of the cubed feeds were chopped to provide lengths of feed $\leq$ 1cm to ensure uniform accessibility for rumen microbial digestion.

Equal portions of each feed, 20g $\pm$ 0.1g were weighed into numbered nylon bags which had previously been dried at 95^{o}C to a constant weight. The bags, 14 X 12cm, were made from "Dacron" with 43um pore size which limited the loss of particulate matter but allowed entry and exit of rumen fluid. An 80cm length of nylon cord was attached to each bag. The bags were securely closed using staples and each cord was threaded through a short length of rubber tubing. The cord allowed the bags to be suspended in the rumen and fully immersed in rumen liquor. The rubber tubing was kept in position by the cannula and prevented loss of the bags in the rumen.

Animals and incubation

Three non-lactating British Fresian and Ayrshire cows were used in the experiment. The cows had been surgically modified at the left para-lumbar fossa, as described by Thyfault, Leffel and Derhuang (1975), and a rumen fistula inserted. The cows were given an all roughage diet of hay.

Sixteen nylon sacs, containing four samples of each of the four feeds were incubated in the rumen of each cow. After intervals of 4, 8, 16 and 24 hours one

bag containing each feed was removed from the rumen of the cows. These bags were then washed thoroughly in cold running water and squeezed to remove rumen liquor and residual micro-organisms.

Chemical Analysis

Fresh samples of each feed and the residual feeds in the bags were dried at 95^{o}C for 48 hours. The weight of dried residual feed was recorded, and the crude protein and ash contents of each was determined (see Appendix 1). The feed samples were analysed and the composition for each is shown in Table 1.7.

Table 1.7 Mean composition of each feed (g/kg) and the weight of nutrients (g) incubated in each sac.

	By-product feed source			
	MSBP	LMSBP	M/DBG	EXT
Fresh Matter (g)	20	20	20	20
Dry Matter	830	875	864	933
Dry Matter Composition				
Crude Protein	107	100	139	113
Organic Matter	907	908	79	936
Ash	93	92	921	63
Nutrients in each sac				
Dry Matter	16.60	17.50	17.27	18.67
Crude Protein	1.77	1.76	2.40	2.12
Organic Matter	15.05	15.89	15.90	17.48
Ash	1.54	1.61	1.37	1.18

RESULTS

Calculation

(Initial weight of nutrient incubated) - (Final weight of nutrient remaining after incubation) = Rumen degradable index of nutrient

Rumen Degradable Protein / Crude Protein (RDP / CP) = Rumen degradable protein coefficient

Rumen Degradable Organic Matter / Organic Matter (RDOM / OM) = Rumen degradable organic matter coefficient

The mean rumen degradability coefficients are shown in Table 1.8 and displayed graphically as percentage degradabilities in Figures 1.1 and 1.2.

The MSBP contained a significant amount of readily degradable organic matter (70%) and crude protein (52%).

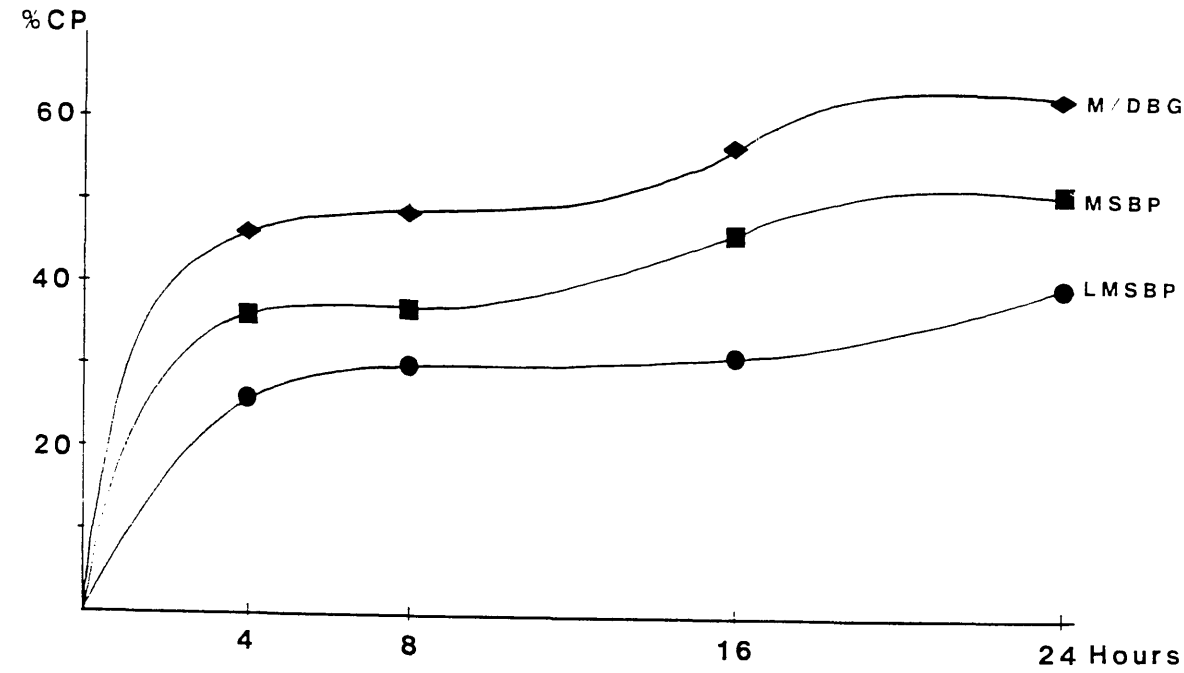
The mixed by-product (M/DBG) contained similar amounts of rumen degradable organic matter, 66% after 24 hr incubation. M/DBG showed a higher value for apparently degradable crude protein (63%) than for any of the other feeds in the study.

The EXT by-product was poorly degraded in the rumen and after 24 hrs more than half the dry matter and organic remained undegraded. There was no evidence of any rumen protein degradation.

The LMSBP by-product contained 60% apparently degraded dry matter and organic matter after rumen incubation for 24 hours, which is similar to other molassed sugar beet pulp by-products. The apparent rumen degradable protein content was low at 43%.

Table 1.8 Mean rumen degradability coefficients and standard deviations for each feed, at intervals within a 24 hour period, when hay was given as the background diet.

		MSBP		M/DBG		EXT		LMSBP	
	hr	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Dry Matter	4	0.42	0.01	0.47	0.02	0.10	0.01	0.34	0.01
	8	0.46	0.06	0.49	0.01	0.12	0.01	0.35	0.06
	16	0.53	0.07	0.63	0.04	0.23	0.04	0.42	0.06
	24	0.64	0.06	0.67	0.02	0.42	0.06	0.60	0.02
Organic Matter	4	0.41	0.03	0.45	0.02	0.10	0.01	0.34	0.03
	8	0.41	0.07	0.48	0.02	0.12	0.03	0.35	0.05
	16	0.70	0.02	0.63	0.04	0.23	0.04	0.37	0.07
	24	0.63	0.06	0.66	0.02	0.42	0.05	0.59	0.02
Crude Protein	4	0.36	0.03	0.47	0.03	< 0.1	ND	0.28	0.01
	8	0.37	0.04	0.49	0.02	< 0.1	ND	0.30	0.03
	16	0.47	0.04	0.58	0.03	< 0.2	ND	0.32	0.03
	24	0.52	0.09	0.63	0.03	< 0.1	ND	0.43	0.01



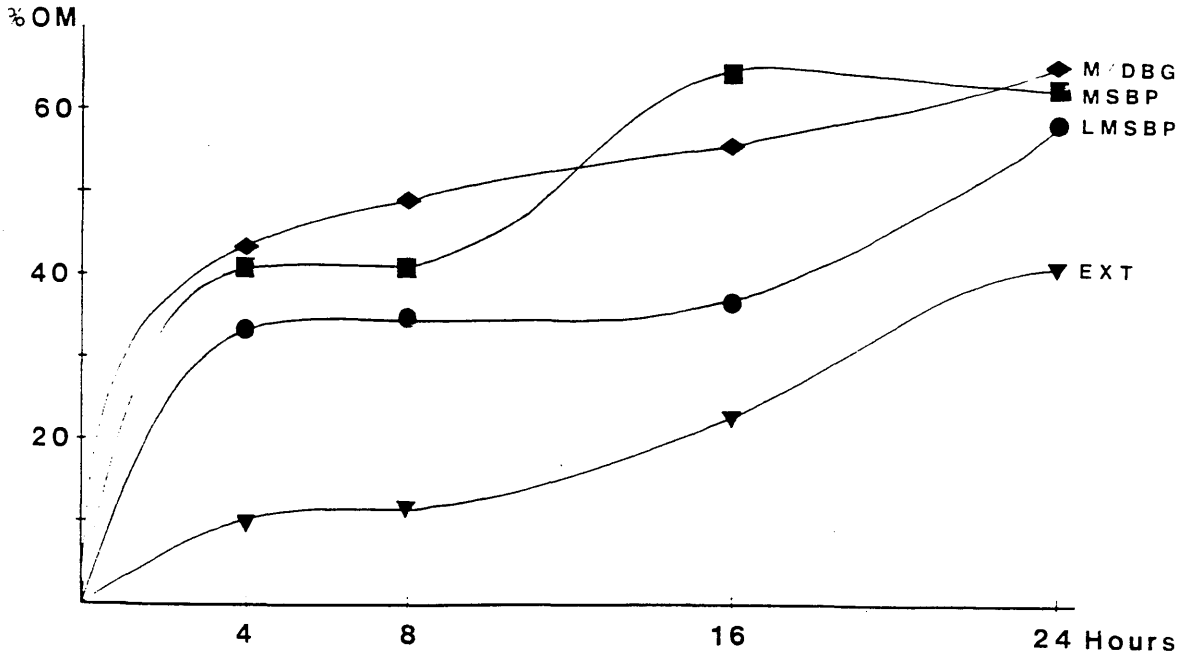


Figure 1.1 The crude protein and organic matter degradability determined over a 24 hour period using three rumen fistulated cows.

DISCUSSION

The results obtained from Experiment 1(a) show that the dried grass nuts were of high quality, with uniform composition and consistent apparent digestibility values were obtained when 18 sheep were used.

The novel by-products were generally well consumed throughout the experiment. The extracted product (EXT) appeared to present some palatability problems and would not be considered suitable as a sole feed source. The mixed by-product was suitable as a sole feed source as no palatability or digestibility problems were observed. The two molassed sugar beet by-products (MSBP and LMSBP) were not considered suitable as sole feed sources due to the presence of highly fermentable carbohydrate which results in soft faeces when fed alone.

The apparent digestibility values determined for M/DBG were almost identical when this product was fed alone or fed with dried grass nuts (DGN). The lower standard error values obtained when M/DBG was the sole feed indicate that this method probably produces more consistent, accurate and less variable results than when the value was obtained by difference. The principle of feeding DGN as a background feed assumes that the digestibility of the test feed is unaffected by the presence of second feed. The results from this experiment confirms the validity of this assumption and the acceptability for calculating apparent digestibility by difference.

The results determined for LMSBP (kg DM) 60g DCP, 765g DOMD, 11.1 MJ ME indicate a nutritionally improved by-product than that first investigated by Abubakar (1989). The unmolassed limed shredded sugar beet pulp by-product described by Abubakar (1989) contained 47g DCP, 763g DOMD and 11.0 MJ ME/kg DM. Both of these novel limed sugar beet pulp by-products compared favourably with a standard molassed sugar beet pulp product 61g DCP, 770g DOMD and 11.5 MJ ME/kg DM.

The high content of rumen undegradable protein (UDP) in EXT indicates the requirement for a supplementary nitrogen source as urea or protein when this by-product is used as a ruminant feed as the crude protein digestibility was less than 10%.

The highly digestible M/DBG mixed by-product containing 63% RDP, 90g DCP/kg DM and 13.0 MJ ME/kg DM may be suitable as a feed for ruminants when a low digestibility forage, such as straw, is fed.

Due to the high costs associated with the direct determination of metabolisable energy (ME) of a feed by animal calorimetry and gas analysis, the ME was calculated using prediction equations and experimentally determined values for DE and DOMD. General equations for compound feeds, DE X 0.832, DOMD% X 0.16, (MAFF, 1984) are available, but equations relating to specific feed sources were considered to be more appropriate.

EXPERIMENT 2. A COMPARISON BETWEEN NORMAL MOLASSED SUGAR BEET PULP AND LIMED MOLASSES SUGAR BEET PULP AS MAJOR COMPONENT OF DIETS GIVEN TO LACTATING EWES.

INTRODUCTION

This experiment was designed to compare a novel limed molassed sugar beet pulp (LMSBP) in a pelleted form, with a standard molassed sugar beet pulp when fed as major dietary components to ewes after lambing. Each ewe was rearing twin lambs and the production parameters measured, throughout the experiment, were liveweight and blood plasma urea, calcium and phosphorus concentrations and lamb liveweight.

MATERIALS AND METHODS

Animals and Management

A total of 57 Greyface ewes in lamb to Suffolk rams were sheared and housed prior to lambing and fed a diet of hay. The concentration feed contained two mixed sugar beet pulp by-products with soya bean meal and dark distillers grains. At lambing the ewe liveweights and lamb birthweights were recorded and each ewe and her lambs were housed in individual pens for 48 hours to ensure maternal bonding and adequate colostrum intake. (Further studies concerning colostrum intake and acquired immunity are described in Section III). After 48 hours the ewes were assessed for body condition score and liveweights recorded.

Twenty nine pairs of ewes and their lambs were arranged on the basis of ewe liveweight and body condition score and lamb birthweights. One ewe from each pair was allocated to one of the two dietary treatments.

All the ewes and lambs were weighed, ewes were assessed for body condition and blood samples taken at the start of the experiment and at three and six weeks post-partum.

Housing

The ewes and lambs were housed throughout the six week trial period on loose straw bedding in a covered yard, with a stocking density of $2m^2$/ewe and trough space approximately 0.33m/ewe.

Feeds and feeding

The two dietary treatments contained either 57% LMSBP or 57% MSBP, in addition to 28% dried dark distillers grains (DDG) and 14% soya bean meal (SBM) on a fresh matter basis. Both dietary treatments contained a salt supplement (1% NaCl) and a trace element and vitamin supplement (0.2% beta-160 supplied by BP Nutrition). The diets were essentially the same except in the origin of the sugar beet by-products, either as LMSBP or MSBP pellets. It was estimated that the two sugar beet pulp products supplied about 55% of the ME and 20% DCP in the concentrate part of the diets. The sheep were fed twice daily, on a group basis, and had free access to drinking water.

During the first three weeks after lambing, each group of ewes received 1.25kg FM hay + 1.25kg FM concentrate mix/head/day.

After three weeks post-partum the dietary allowances were increased, on a daily basis, to 1.5kg FM hay and 1.5kg FM concentrate mix/head.

During the first three weeks of the experiment the lambs were dependant upon suckling ewes milk to obtain the nutrients required for growth. At three weeks of age the lambs were given access to a creep feed of hay alone.

Feed sampling

Representative feed samples were taken throughout the experiment and dried prior to determination of the proximate composition. The feed compositions are displayed in Table 2.1

Blood sampling

10ml blood samples were taken from the jugular vein using heparinised vacutainers. The blood was separated in order to obtain plasma for determination of urea, calcium and phosphorus concentrations.

RESULTS

The mean composition of the feeds is shown in Table 2.1 together with ME and DCP values derived from prediction equations or determined in vivo.

Table 2.1 Mean Composition of the feeds (g/kg) used during the trial.

	MSBP	LMSBP	HAY	SOYA	DDG
Dry Matter	849	863	829	869	901
Dry Matter Composition					
Crude Protein	108	102	49	547	336
Crude Fibre	149	159	342	40	93
MAD Fibre	173	192	339	52	124
Ether extract	3	3	8	12	47
Ash	92	88	54	71	37
Organic Matter	908	912	946	929	963
N.F. Extract	648	648	547	330	487
Calcium	11.98	13.21	3.25	2.92	1.07
Phosphorus	0.84	1.05	1.48	7.28	7.19
Gross Energy (MJ)	15.7	16.00	17.4	19.3	20.0
ME (MJ)	11.5^a	11.1^a	9.3^b	13.4^c	11.6^d
DCP	61^a	60^a	8^b	453^c	219^d
DOMD	769^a	765^a	75^b	844^c	640^d

a Values calculated from digestibility results obtained in Experiment 1.

b Values calculated using prediction equations (MAFF, 1984)

ME = 16.53 - 0.0213 MADF

DCP = 0.91 X CP - 36.7

DOMD% = 0.92 X OMD% - 1.2

c Values obtained from standard tables (MAFF, 1986)

d Values obtained from literature (Taylor and Parkins, 1989)

During the trial two lambs died and one ewe in very poor condition was given extra concentrate feed. When the trial was completed a further six ewes and their lambs were excluded from the trial data due to abnormally low liveweight gain,

poor health or death of a lamb. These were not considered to be associated with the dietary treatment. This enabled the data to be analysed on the basis of each ewe successfully rearing twin lambs. The final analysis was conducted for 26 ewes fed MSBP, rearing 52 lambs, 29 female and 23 male. Data for 25 ewes fed LMSBP, was analysed, with 50 lambs being reared, 26 male and 24 female.

The diets were well consumed and no palatability problems were encountered for either sugar beet pulp by-product. All the ewes came forward to the troughs to consume the concentrate mixtures and hay. Some ewes were observed to persist longer than others at the hay racks. The principal results are given in Table 2.2 The overall mean birthweight of the twin lambs was 5.25kg which was considered satisfactory for the breed of sheep and husbandry system employed. During the whole experimental period of six weeks, the mean liveweight gain for the lambs from ewes given LMSBP was 9.74kg (232g/day) and the lamb liveweight gain from ewes given MSBP was 10.13kg (241g/day). There were indications that the daily liveweight gains from 0-3 weeks (251 and 263g) were larger than those from 3-6 weeks (212 and 220g respectively) perhaps due to declining milk yields after three weeks.

During the first three weeks, the loss in liveweight of the ewes was 5.6kg for those given LMSBP and 5.7kg for those given MSBP. During the 3-6 week period after lambing the ewes gained a little liveweight (0.3kg for ewes given LMSBP and 1.0kg for ewes given MSBP). This was perhaps an indication of increased body fill as the serious reduction in body condition score for both groups over the first three weeks (2.3 - 1.9 and 2.4 - 1.8) appeared to have been arrested. The increased allocation of hay and concentrates was obviously an important factor.

The mean plasma urea concentrations increased throughout the experiment. The increased plasma urea concentrations from 3 to 6 weeks after lambing probably reflects the increased rate of feeding. Normal blood calcium and phosphorus concentrations were maintained for the duration of the trial.

There were no significant treatment differences for any of the parameters measured at any stage of the experiment.

Table 2.2 Mean ewe liveweight (kg), condition score and plasma metabolite concentrations (mmol l^{-1}) and mean lamb liveweights (kg) for each diet, including the standard errors.

		Diets			
		LMSBP		MSBP	
Weeks after lambing		mean	SEM	mean	SEM
Ewe liveweight	0	65.9	1.62	65.7	1.55
	3	60.3	1.70	59.0	1.70
	6	60.6	1.55	60.0	1.51
Ewe body condition score					
	0	2.4	0.09	2.3	0.11
	3	1.8	0.12	1.9	0.12
	6	1.7	0.10	1.7	0.10
Lamb liveweight					
	0	5.17	0.21	5.39	0.17
	3	10.45	0.21	10.91	0.29
	6	14.91	0.41	15.52	0.43
Plasma urea					
	0	2.95	0.19	3.55	0.35
	3	6.14	0.28	6.34	0.24
	6	8.08	0.25	8.89	0.33
Plasma calcium					
	0	2.25	0.03	2.26	0.02
	3	2.45	0.04	2.40	0.02
	6	2.53	0.04	2.50	0.03
Plasma Phosphorus					
	0	1.61	0.11	1.67	0.09
	3	1.78	0.07	1.70	0.07
	6	1.75	0.06	1.84	0.05

DISCUSSION

The mean lamb liveweight gain and the mean loss in mean ewe liveweight and reduction in body condition score in this experiment were very similar to those recorded in similar experiments conducted with the same type of sheep in similar husbandry conditions. Bass, Fishwick and Parkins (1980). Ducker, Fraser and Hemingway (1976).

Three weeks after parturition the increase in food allocation was designed to provide extra nutrients to meet the increased demand during lactation as the ewes appeared to be losing appreciable amounts of liveweight. The lambs were also allowed access to a creep feed of hay alone, in order to stimulate rumen function. The introduction of a solid feed source facilitates rapid weaning of lambs and helped to reduce the lactational stress upon the ewes.

The ME and DCP requirements of 66kg ewes, suckling twin lambs with a liveweight gain of 240g/day was calculated as 240 x 2 x 5 = 2.4 litres milk/day to be 26 MJ ME (MAFF, 1984) and 276g DCP (ADAS, 1976). These estimated requirements assumed that there was no liveweight loss. Table 2.3 describes the supply of ME and DCP in the diets, throughout the experiment and for earlier experiments performed under similar conditions by other workers.

The diet given to ewes rearing twin lambs by Ducker, Fraser and Hemingway (1976) containing molassed sugar beet pulp and urea did not meet the calculated dietary requirements for ME and DCP. The consequence of this was a dramatic reduction in ewe liveweight (15% of total body weight) and a reduced lamb growth rate (192g/day).

The diets fed to ewes by Abubakar (1989) contained unmolassed sugar beet pulp by-products, either limed (LSBP) or normal unmolassed sugar beet pulp (USBP). There was little difference observed between the two treatments and Abubakar (1989) noted the equivalent value of feeding these by-products to lactating or pregnant ewes.

Table 2.3 Mean dietary intake of ME (MJ) and DCP (g) during the first three weeks of lactation and the associated ewe liveweight loss (kg) and lamb liveweight gain (kg) for three experimental trials.

	Present Study		Abubakar (1989)		Ducker, Fraser & Hemingway (1976)
	LMSBP	MSBP	LSBP	USBP	MSPB & Urea
ME Intake	22.4	22.5	20.9	21.3	15.4
DCP Intake	216	216	238	241	146
Ewe Liveweight loss					
3 weeks	5.6	5.7	5.6	6.1	ND
4 weeks	ND	ND	ND	ND	10.7
Lamb liveweight gain					
3 weeks	5.3	5.5	5.3	5.2	ND
4 weeks	ND	ND	ND	ND	5.4

ND = not determined

The diets containing molassed sugar beet pulp by-products investigated in the current study, either limed (LMSBP) or normal (MSBP) by-products contained slightly less DCP than those investigated by Abubakar (1989).

The diets did not supply sufficient ME and DCP to meet the full requirements defined by MAFF (1984) ADAS (1976) but no appreciable difference was observed between the different treatments, for ewe liveweight loss or lamb liveweight gain.

Three weeks after parturition the increased feed allocations raised the ME and DCP contents of the LMSBP diet to 26.8 MJ and 261g DCP and MSBP diet to 26.9 MJ and also 261g DCP, respectively. During this period, 3-6 weeks post-partum, lamb liveweight gain was 212g/day for ewes receiving LMSBP and 220g/day for ewes receiving MSBP and a small increase in the mean ewe liveweight was observed for ewes on both dietary treatments.

This study has shown that LMSBP is of comparable value to normal MSBP for feeding to ewes during lactation, rearing twin lambs. The ewe liveweight loss is an anticipated effect of the feeding regime and is considered an acceptable practice

to minimise feed costs. The ewes soon regained body condition and gained liveweight when they were transferred onto spring pasture and the lambs started eating solid feed.

SECTION II

DISTILLERY BY-PRODUCTS AS RUMINANT FEEDS.

BACKGROUND REVIEW

The use of cereal-based by-products from the distilling industry has become increasingly important in the animal feed industry in recent years. The high energy and protein content of some distillery by-products makes them an attractive alternative to conventional protein sources.

Whisky production

Whisky production in Scotland 1988 was 452 hectolitres of alcohol (Statistical Abstracts, 1990). Whisky distilleries in Scotland are either 'malt' or 'grain' types, depending upon the substrate source and fermentation process. Malt whiskies are produced using barley as the source of fermentable sugars, the value of a malt whisky being classified by the length of time for maturation. (Legal requirements stipulate a minimum of three years.)

Only specific varieties of barley, which meet the requirements of the distillery, are used as malting barley. The malting process is achieved by steeping the grain in water at standardised conditions of time and temperature. Germination conditions are reached when the moisture content of the grains increases to approximately 45%, after which the grain is spread and turned regularly under controlled conditions of aeration and temperature. After about twelve days the rootlets wither and the grain, which has a mealy appearance, is kiln dried and cooled. The malt is then screened for impurities and the "malt culms" are separated. The malt is coarsely ground before 'mashing' with hot water to remove a series of extracts to form a solution known as wort. The solid residue remaining after extraction is known as malt distillers grains (MDG).

The production of malt whisky is a batch process, conducted on a relatively small scale in many small distilleries. In contrast grain distilleries are much larger establishments producing virtually pure alcohol known as "grain whisky". Blended whisky is a mixture of grain whisky with different proportions of several unique flavoured malts. Grain distillers use unmalted cereals as the major substrate for

whisky production such as barley, maize, wheat, oats or rye. The European Common Agricultural Policy has contributed to reductions of imported maize, the former principal substrate for whisky production, and consequently has influenced the increase in use of home produced cereals.

The change of raw materials has altered the concept of cereals in the distilling industry and also the processing techniques employed. Technology for alcohol production, in terms of brewing and distilling, has developed a characterisation of cereal substrates according to milling energy, sedimentation rate, extract viscosity, enzyme activity (particularly alpha- and beta-amylase), protein proportion in the grain and protein quality. (Whitehouse, 1977) Most research has been applied to barley, but the increasing importance to wheat as a replacement for maize has provoked the need for a definitive characterisation of wheat varieties. This cereal characterisation, coupled with the advances in biotechnology, may generate specific cultivars which possess the salient properties for efficient whisky production with valuable by-products.

The development of processing techniques for whisky production in Scotland, using wheat grains as the major substrate, has created (inter alia) the production of a novel by-product, wheat distillers SUPERGRAINS (SG). The wheat is coarsely ground with a small quantity of malting barley and 'mashed' with hot water. The presence of enzymes in the malt assist in the conversion of wheat starch to soluble sugars. The addition of yeast to the mix promotes the fermentation of sugars to alcohol, after which it is transferred to copper pot-stills and heated to distil off the alcohol. The last distillation generates the final spirit which is matured in wooden casks. The remaining material is concentrated by centrifugation and further dewatered by a screw press to produce the wheat distillers SUPERGRAINS (SG). SG is a succulent by-product approximately 27% dry matter containing 'spent' wheat grains and yeast.

The use of distillery by-products for animal feeding is extensively practised particularly in whisky producing areas. Livestock producers in Scotland benefit from a local supply of, generally undried, unique animal feed sources of virtually constant composition. Local deliveries reduce transport costs and regular orders

reduce the problems associated with storage. Close contact between the consumer and producer enables the supply and demand of the by-products to be efficiently managed during periods of maximum and minimum production. Production at malt distilleries traditionally ceases for a few weeks during the summer period and inevitably undried by-products must be stored on farms to minimise spoilage.

The use of distillery by-products as animal feeds.

Animal feeds containing the spent grains from the brewing industry have been used for a long time as wet brewers grains. Spent grains from the distilling industry have traditionally also been used as wet grains for animal feed. For example, Loosli and Warner (1958) have reported the value of these two by-products as energy and protein supplements for dairy cows.

These wet by-products discharged effluent into the natural waterways during storage and until 1965 (Rivers Act 1965) the distilleries also discharged effluent, as spent wash, directly into the waterways. The Biological Oxygen Demand (BOD) of this effluent is 100 times greater than that for untreated sewage. Viable alternatives were required to stop the pollution and to utilise the waste by-products. Feeding spent wash with low-quality roughages to cattle was of limited value when used as the sole supplement (Sheehan, Topps and Miller, 1970) due to the inferior mineral composition, and low dry matter content.

Research developed a process to dry the distillers grains to form distillers dried grains (DDG) and the spent wash was partially evaporated to produce Pot-ale syrup. Further drying of the Pot-ale syrup produced distillers dry solubles (DDS). These by-products have been used individually as animal feeds by a material with a higher protein content than DDG was formed by condensing the syrup on to the DDG to form a product called wheat dark distillers dried grains (WDDG). Taylor and Parkins (1989) described the potential of this wheat distillation by-product as a feed source for ruminants, 11.6 MJ ME, 219g DCP/kg DM. The range of distillery by-products has been described by the North of Scotland College of Agriculture (NOSCA, 1984) both as on-farm feeds and as constituents of compound diets. Ruminants and non-ruminants are able to utilise distillery

by-products but special consideration is required for non-ruminant diets in terms of the fibre content and protein quality of the by-products.

Although distillers dried grains and brewers dried grains are considered to be resistant to ruminal protein degradation (Waller, Klopfenstein and Poos, 1980; Merchen, Hanson and Kloftenstein, 1979). This can provide efficient protein utilisation in young beef cattle when there is an adequate supply of NPN. Proteins of low rumen degradability may be of special value for high yielding dairy cows provided the protein is subsequently digested.

The high costs in terms of water usage and fuel consumption required to dry distillers grains and in the evaporation of spent wash have maintained the search for alternative by-product production processes. The Department of Agriculture and Fisheries for Scotland (DAFS, 1984) reported on a commercial by-product which did not employ separation of the grains in the whisky production process. It appeared to be a suitable by-product feed for ruminants with a high protein (388g/kg DM) and oil (111g/kg DM) content with an energy value, 15.7 MJ ME/kg DM. The very low mineral content would make the by-product unsuitable as a sole supplement, and additional minerals (principally salt, calcium and magnesium) must be supplied.

The use of malt distillers grain, from a local distillery (MDG) in this study, as a somewhat comparable feed source to SG, has been evaluated in terms of storage and composition qualities (Miller 1969). NOSCA (1969) reported the value of distillers grains (draff) in animal feeds. MDG has been shown as an easily digestible and metabolisable feed source for growing lambs (Reveron, Topps and Pratt, 1970) and the energy value (10.8 MJ ME/kg DM) and protein content (207g DCP/kg DM) (Wainman and Dewey, 1982) has demonstrated it as a valuable source of energy and protein. Increased voluntary feed intakes of MDG were noted (Miller, El Hag and Pratt, 1970) when calcium supplements were provided, although digestibility was unaffected.

Present study of distillery by-products

This study investigated the potential of SG as a feed for ruminants in terms of an energy and protein source for dairy cows with particular reference to milk composition and yield in contrast to a normal barley draff. A separate study investigated the production potential of spring calving beef suckler cows when given a diet of SG and hay. Spring calving suckler herds have traditionally been in-wintered on diets of restricted energy and protein intakes to reduce costs. There is normally an acceptable loss in body condition of the cows before transfer to grass in the spring when the body condition scores improve and the cows are remated. Miller (1977) illustrated the physiological adaptation of particular cow breeds to situations of stress, and demonstrated the ability of dairy X beef cross bred cows to maximise their genetic traits in terms of milk production and rapid calf liveweight gain.

The use of experimental sheep, in metabolism crates, provided an in vivo technique for determination of the nutritive value of SG and the other feeds used.

The storage and palatability qualities of SG were considered in this study in order to assess the practical application of this feed to realistic farm situations.

EXPERIMENT 3 DETERMINATION OF THE NUTRITIONAL VALUE OF TWO DISTILLERY BY-PRODUCTS WHEAT DISTILLERS SUPERGRAINS (SG) AND MALT DISTILLERS GRAINS (MDG) AND TWO COMMERCIAL DAIRY CONCENTRATE FEEDS (DCFMIX).

INTRODUCTION

This study was concerned with the assessment of SG, a novel by-product from the distilling industry, in terms of its definitive nutritive value, the results of which will be referred to later in animal production experiments.

A comparative study was performed throughout these evaluation experiments in order to quantify the metabolisable energy (ME) and digestible crude protein (DCP) contents of SG and MDG, and SG and DCFMIX. DCFMIX contained equal parts of two proprietary concentrate feeds (DCFI and DCF2) designed for feeding to lactating dairy cows. Experiment 3(a) was designed to determine the nutritive value of these feeds. The use of SG as a feed for beef suckler cows is fully described in Experiment 4 and Experiment 5 involved a comparison between SG and MDG as feeds for dairy cows.

Experiment 3(b) was designed to evaluate the extent of ruminal degradation of the nutrients in SG and MDG.

Experiment 3(a) Digestibility with sheep.

MATERIALS AND METHODS

A detailed description of digestibility studies performed using sheep in metabolism crates for total faecal collection has been described in Experiment 1. Twenty four wether sheep were paired according to liveweight and arranged into groups of six comparable sheep. Each group was given one dietary treatment and were housed in metabolism crates for the duration of the trial. The sheep were fed twice daily, the fresh matter content of each diet per head per day was as follows:-

Diet 1 1500g MDG + 500g DGN (Dried Grass Nuts)

Diet 2 1500g SG + 500g DGN

Diet 3 800g DCF1 + 400g DGN

Diet 4 800g DCF2 + 400g DGN

The mean liveweights (kg) of the sheep given diets 1-4 were respectively, 47.8, 48.9, 42.5 and 42.0 kg. The trial lasted 14 days and representative subsamples of total faecal output, collected over the final 7 days, were analysed to determine the proximate composition, gross energy value and macroelement concentration. Representative feed samples were taken throughout the experiment and analysed to determine the proximate composition, gross energy value and mineral content of each feed. The proximate composition of feeds is displayed in Table 3.1. The apparent digestibility of the dried grass nuts had previously been determined and is described in Experiment 1(a). It was assumed that the digestibility of the dried grass was not affected by the presence of other feeds.

Table 3.1 Proximate composition of feeds (g/kg) used in the digestibility study with sheep.

	SG	MDG	DCF1	DCF2	DGN
Dry Matter	280	247	854	867	898
Dry Matter Composition					
Crude Protein	351	212	182	175	250
Crude Fibre	186	223	112	125	229
Ether Extract	95	82	59	46	45
Ash	19	34	135	122	91
N-Free Extract	349	448	512	532	385
Organic Matter	981	965	865	878	909
Calcium	1.29	1.33	16.4	14.8	5.85
Phosphorus	2.95	3.84	6.96	8.09	2.99
Copper (mg)	144	16.4	ND	ND	ND
Gross Energy (MJ)	22.2	21.0	17.4	17.6	18.6

ND = not determined

RESULTS

Calculation

From the analytical results for faecal and feed composition the digestibility coefficients for nutrients within each feed was calculated using the identity: -

$$\text{Apparent digestibility} = \frac{\text{Total [nutrient] Feed Intake - Total [nutrient] faecal output}}{\text{Total [nutrient] faecal intake}}$$

for a single product and

$$\text{Apparent digestibility} = \text{By-product [nutrient] intake} - \text{Total [nutrient] faecal output} - (\text{1-apparent digestibility coefficient for DGN}) \times \text{DGN [nutrient] intake}$$

By-product [nutrient] intake for a diet containing 2 feeds.

[nutrient] - DM, CP, CF, OM, GE.

The mean apparent digestibility coefficients, given in Table 3.2, and the SEM values, demonstrate that there was minimal error during the trial, either as animal variation, experimental procedure or analytical technique. (SEM $\leq$ 0.30). For statistical interpretation of the results the students t-test was applied to the mean apparent digestibility values. The total dry matter digested for SG (72.5%) was significantly higher than for DCF1, DCF2 and MDG, 63.5%, 62.0% and 59.4% respectively. The apparent organic matter digestibility of SG (725g/kg DM) was greater than either of the dairy feeds or MDG. The crude fibre contents of the concentrate feeds were only 29.4% and 36% apparently digestible, and only about half the apparent digestibility of that of SG (72%). The apparent digestibility of MDG crude fibre was 53%. There was no significant difference in the crude protein digestibility of the two distillery by-products, although the quantity of DCP in each feed was different, MDG (152g/kg DM), and SG (249g/kg DM). The apparent digestibility of crude protein for the dairy concentrate feeds was significantly less than for SG (71%), and the total digestible crude protein content of the feeds DCF1 (121g/kg DM), DCF2 (110g/kg DM) was also less than for SG. The ME values, which were calculated using various prediction equations, were higher for the distillery by-products (12.1 MJ/kg DM, 13.6 MJ/kg DM) than for the dairy concentrate feeds (9.5 and 9.8 MJ/kg DM). SG had the highest ME value 13.6 MJ/kg DM. Further discussion of the ME values is given in the discussion.

Table 3.2 Mean digestibility coefficients determined using sheep for the 4 feed samples

	MDG		SG		DCF1		DCF2	
	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM
Dry Matter	0.694***	0.008	0.725	0.013	0.635***	0.011	0.620***	0.006
Crude Protein	0.718NS	0.018	0.709	0.009	0.663**	0.011	0.629***	0.009
Organic Matter	0.610***	0.009	0.739	0.009	0.672**	0.013	0.660***	0.006
Crude Fibre	0.534***	0.011	0.717	0.015	0.294***	0.021	0.360***	0.030
Gross Energy	0.655***	0.010	0.738	0.008	0.658**	0.020	0.671***	0.006
DCP g/kg DM	152		249		121		110	
DOMD g/kg DM	589		725		582		580	
DE MJ/kg DM	13.76		16.41		11.44		11.82	
MJ/kg DM	11.4[a]		13.6[a]		9.5[a]		9.8[a]	
ME	12.1[c]		14.5[b]		9.1[d]		9.0[d]	
	11.96[e]		15.4[f]					
	10.2[g]		12.0[g]					
	10.7[h]		13.9[h]					

Significance levels, relative to SG

***	P < 0.001
**	P < 0.005
*	P < 0.01
NS	not significance

Prediction equations for calculation of ME, used in Table 3.2 (Wainman, Dewey and Brewer, 1984).

a) DE X 0.83	General equation for compound feeds
b) DE X 0.884	Specific equation appropriate to particular by-product
c) DE X 0.879	Specific equation appropriate to particular by-product
d) DOMD% X 0.156	General equation for compound feeds
e) DOMD% X 0.213	Specific equation appropriate to particular by-product
f) DOMD% X 0.203	Specific equation appropriate to particular by-product
g) ME = 2.4+0.133 DOMD%	General equations for distillery by-products
h) ME = - 17.9 + 0.178 DOMD% + GE (MJ/kg OM)	"

The equations used are based upon in vivo determinations of DE and DOMD and GE of the feed. DAFS (1984) reported the ME values of distillery by-products and other compound feeds from the evaluation of faecal, urinary and methane energy losses. Analysis of a distillery by-product (similar to SG) and malt distillers draff enabled direct use of the specific equations for these by-products.

Experiment 3b Rumen degradability studies

MATERIALS AND METHODS

A detailed account of in sacco rumen degradability studies, using rumen fistulated cows, is described in Experiment 1. Four feed samples were used in the experiment, wheat distillers SUPERGRAINS (SG), malt distillers grains (MDG) and two different commercial dairy concentrate feeds (DCF1 and DCF2) in pellet form. All the feeds were in a form suitable for direct use.

Sixteen nylon sacs containing four samples of each of the four feeds, ie. undried distillers by-products, 40 $\pm$ 0.1g FM and concentrate feeds 20 $\pm$ 0.1g FM, were incubated in the rumen of three cows fitted with a standard rumen fistula (Avon

Products Ltd.). The bags were removed at 4, 8, 16 and 24 hr intervals. The contents were washed and dried before the weighed residual feed was analysed to determine the crude protein and organic matter contents. (Appendix 1) The original fresh feeds were analysed and the composition of each is shown in Table 3.3.

Table 3.3 Mean composition of each feed (g/kg) and the weight of nutrients (g) incubated in each sac.

	Feed Source			
	MDG	SG	DCF1	DCF2
Fresh Matter (g)	40	40	20	20
Dry Matter	246	284	870	872
Dry Matter Composition				
CP	220	330	172	163
OM	968	978	867	884
Ash	32	22	133	116
Nutrients in each sac				
DM	9.84	11.34	17.39	17.45
CP	2.16	3.75	2.99	2.84
OM	9.52	11.09	15.08	15.42
Ash	0.32	0.25	2.31	2.03

RESULTS

Calculation

The degradability coefficients for crude protein and organic matter were determined from the fresh and residual feed weights and composition:

(Initial weight of) nutrient incubated - (Residual weight of nutrient) remaining after incubation = Rumen degradable index of nutrient

$\frac{RDP}{CP}$ = Rumen degradable protein coefficient

$\frac{RDOM}{OM}$ = Rumen degradable organic matter coefficient.

The results are given in Table 3.4, as rumen degradability coefficients for crude protein, organic matter and dry matter, and displayed graphically in Figures 3.1 and 3.2.

The apparent degradability of the organic matter increased with time, the maximum apparent degradability values for DCF1 (62%) and DCF2 (54%) being at 24 hours. The higher crude fibre content of the distillery by-products, SG (185g/kg DM) and MDG (223g/kg DM) may account for the somewhat lower organic matter degradability of these two feeds in the rumen after 24 hr incubation.

Table 3.4 Mean rumen degradability coefficients for each feed at intervals within a 24 hour period when hay was used as the background diet.

		SG		MDG		DCF1		DCF2	
	hr	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
Dry Matter	4	0.19	0.04	0.27	0.01	0.43	0.03	0.39	0.05
	8	0.26	0.06	0.25	0.07	0.49	0.04	0.42	0.08
	16	0.41	0.08	0.33	0.03	0.58	0.04	0.55	0.06
	24	0.50	0.03	0.52	0.03	0.62	0.02	0.55	0.08
Organic Matter	4	0.19	0.04	0.23	0.05	0.43	0.03	0.39	0.05
	8	0.26	0.07	0.25	0.07	0.49	0.04	0.42	0.08
	16	0.42	0.08	0.34	0.01	0.58	0.03	0.50	0.007
	24	0.51	0.04	0.52	0.02	0.62	0.02	0.54	0.08
Crude Protein	4	0.30	0.07	0.28	0.09	0.42	0.03	0.29	0.06
	8	0.39	0.08	0.47	0.02	0.48	0.09	0.39	0.00
	16	0.53	0.11	0.57	0.03	0.60	0.07	0.45	0.07
	24	0.57	0.06	0.73	0.01	0.63	0.03	0.40^{+}	0.01

$^{+}$ possible erroneous value

Crude protein degradabilities of the two dairy concentrate feeds were DCF1 (63%) and DCF2 (40%) indicating that approximately half the feed protein, containing a mixture of the feeds, remains undegraded after 24 hr rumen incubation. 73% of the crude protein in MDG was apparently degraded and this by-product obviously

contains a rapidly degradable protein source. SG contains crude protein which is apparently 57% degraded after 24 hrs incubation.

Orskov (1977) considered that protein degradation rates could be quoted when 90% of the dry matter has been degraded. For the products investigated the apparent degradability of dry matter did not exceed 61% and no definitive values for the rate of degradation can be given.

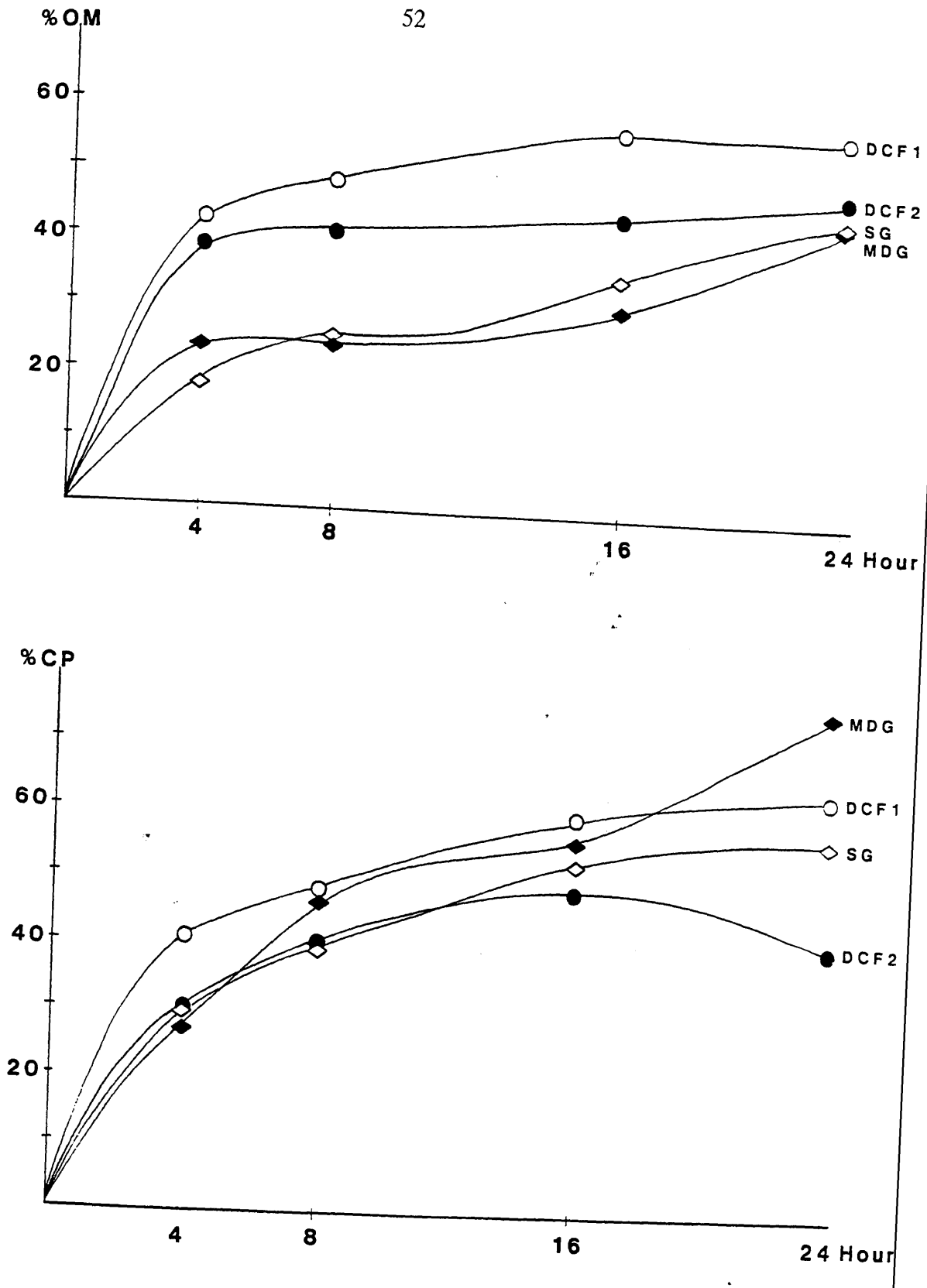


Figure 3.1 The organic matter and crude protein degradability determined for four feeds over a 24 hour period using three fistulated cows.

DISCUSSION

Digestibility and rumen degradability data in terms of the nutritive value of wheat distillers SUPERGRAINS.

The gross energy of SG is high due to high OM and high oil content. A high GE value (22.2 MJ/kg DM) of SG produces a high digestible energy content (16.41 MJ/kg DM). Many of the frequently used prediction equations for ME determination are now obsolete (MAFF, 1984) as new information is published. Recent publications for predictive equations for ME determination from in vivo DOMD and DE values have been quoted for compound feeds (DAFS, 1984).

ME = DOMD X 0.156

ME = DE X 0.83

Particular equations have been defined for distillery by-products:

ME = 2.4 + 0.133 DOMD%

ME = -17.9 + 0.178 DOMD% + GE (MJ/kg OM)

and specific equations have been applied to a similar by-product of grain whisky production:

ME = DE X 0.884

ME = DOMD% X 0.213

The determination of ME using sheep in metabolic respiratory chambers has determined urinary, faecal, and methane energy losses. The methane energy loses were much lower than expected (< 5% GE, DAFS, 1984) and consequently the ME prediction equations were modified accordingly.

The most reliable estimation of ME is likely to be than which considers the DE of SG, determined in vivo. From this the calculated value is 14.5 MJ ME/kg DM and this value will be referred to in Experiment 4 and Experiment 5. The values for DCF1 and DCF2, 9.5 and 9.8 MJ ME/kg DM, were calculated from in vivo determined DE values and will be referred to in Experiment 4 and Experiment 5.

The definitive nutritive value of SG, as determined in this study describes a material containing 280g/kg DM of which 72.5% is degraded in the rumen after 24 hours. After a 24 hour incubation period 142g/kg crude protein is degraded. The digestible crude protein content of SG was 249g/kg DM. Many authors (eg. Alawa, Fishwick, Parkins and Hemingway, 1986) have reported that protein supplements improved the apparent digestibility of roughages. A large proportion of SG exists as UDP after 24 rumen incubation. This may be due to the very high crude protein levels in the feed (351g/kg DM) or the high oil content (95g/kg DM) which may influence rumen degradation by reducing protein degradation (Czerkawski and Clapperton, 1984). SG has a readily digestible organic matter content (approximately 50% DM degraded in the rumen after 24 hours) 50% OM rumen degradable after 24 hours.

The highly digestible crude fibre fraction of SG indicates a source of readily available soluble and structural carbohydrates. Fibre digestion in ruminants involves a wide variety of cellulytic micro-organisms, bacteria, protozoa and fungi (Hungate, 1970). Further detailed analysis of SG in terms of NDF, ADF and NCD would yield more information concerning the fibre composition. These nutritive evaluation experiments only consider the whole animal digestion, and only slight consideration is given to the ruminal digestive processes (in Experiment 3(b)). Greater consideration needs to be given to the rumen form and function when feeding these novel by-products. The rumen degradability experiment should ideally be carried out on fistulated animals which have been fed a diet of the feed under test for a considerable period of time to allow for ruminal adaptations.

Ruminal adaptations should also be investigated in terms of rate of passage of substrates, microbial populations and relative proportions of volatile fatty acids produced. These factors all contribute to the nutritional value of feed by-products for ruminants. The extent of post-ruminal digestion and fate of the end-products must also be assessed. The ash fraction of SG is extremely low (19g/kg DM) and considering the mineral requirements of a 500kg pregnant beef cow, 7 weeks pre-partum, Ca 15g/day, P 18.4g/day, Mg 11.9g/day (ADAS, 1983) it is obvious that further investigations need to be performed concerning the mineral content. A general purpose mineral supplement added to SG as a sole concentrate feed source

may not be appropriate. The copper content of SG is very high, and the short duration of the sheep trial was not expected to produce copper toxicity problems. Cattle are not as sensitive to high copper intakes, but consideration of the cumulative effects of feeding copper to cattle needs to be addressed. The potential for liver damage and residual accumulation in muscle tissue may introduce increasing quantities of copper into the human food chain.

The proprietary dairy concentrate feeds (DCF1 and DCF2) were comparable in terms of proximate analysis (g/kg FM), crude protein 155 and 152, crude fibre 96 and 108, ether extract 50 and 40, and ash 115 and 106. They were also comparable in terms of digestible crude protein (121 and 110g/kg DM) and metabolisable energy (9.5 and 9.8 MJ/kg DM). These low ME values are probably due to a high ash content and reduced digestibility. Hemingway (1983) reported on the nutritional value of "high energy" compound feeds for dairy cows, with a mean crude protein digestibility coefficient of 0.74 $\pm$ 0.043 and ME value of 10.0 - 10.5 MJ. The values obtained in this study for DCF1 and DCF2, "medium quality" concentrate feeds (commercial specifications CF 16%, oil 6%, fibre 9.5%, ash 11%) compare unfavourably with mean crude protein digestibility coefficients of 0.663 $\pm$ 0.011 and 0.629 $\pm$ 0.009. The dairy concentrate feeds were combined to provide a dietary feed source which eliminated bias from feeding one proprietary brand only.

EXPERIMENT 4 WHEAT DISTILLERS SUPERGRAINS (SG) AS A FEED SOURCE FOR BEEF COWS DURING PREGNANCY AND LACTATION

INTRODUCTION

The objectives of this study were to observe beef suckler cows on a feeding trial (containing SG) and record the dietary effects in terms of cow liveweight, body condition score and blood metabolite concentrations, during pregnancy and lactation calf growth rates were recorded during lactation. The effects of the diet containing SG were assessed in relation feeding a comparative proprietary feed source to a second group of beef suckler cows. Digestibility values were determined over a 14 day period during late pregnancy, using an indigestible marker system for both diets, as it was not practicable to undertake total faecal collection. Chromium sesquioxide (Cr_2O_3) was the marker of choice having been shown to be the most satisfactory marker tested, (Corbett, Greenhalgh, Gwynn and Walker, 1958) when used in conjunction with exact feed intakes. The results obtained in Experiment 3 enabled the nutrient dietary intake to be assessed and compared with recommended nutrient allowances for pregnant and lactating cattle. The storage and palatability qualities of SG were also determined during the 16 week trial period.

The use of Hereford X British Friesian suckler cows mated to a Charolais bull in this study is appropriate to a commercially run farm and the diets and management procedures were also appropriate to those used in a commercial environment.

MATERIALS AND METHODS

Animals and Management

A total of twenty two pregnant beef cows (mainly Hereford X British Friesian and some Irish Blue Grey) in calf to a Charolais bull and expected to have a gestation period of 286 days, were used in the trial. Initially, thirty seven cows were housed about 20 weeks from calving and introduced to a diet of hay and wheat distillers SUPERGRAINS (SG). The cows were given on a daily basis, 6 kg fresh matter hay and SG in gradually increasing amounts up to a maximum of 10 kg of fresh matter. Any feed refusals were recorded which identified particular cows which were not suitable to use in a feeding trial with SG as a major feed source. A proprietary

concentrate feed source (DCFMIX) was used as a comparative feed source and is fully described later.

From the original group of 37 cows, 22 cows were chosen for the trial according to their willingness to consume SG and their predicted calving dates. This was to ensure that the cows on the trial all calved within a 4-week period. At ten weeks before calving the cows were weighed, the body condition scores (Lowman, Scott and Somerville (1973), Scottish Agricultural Colleges (1984) assessed and blood samples taken, in order to pair the cows on the basis of these parameters. One cow from each pair was allocated to one of two different dietary treatments and all were individually fed for the duration of the trial. The mean values for each group of 11 cows for liveweight, body score and anticipated days from calving were respectively, 502kg, 2.4, 67 days for Treatment 1 (SG) and 498kg, 2.4 and 68 days for Treatment 2 (DCFMIX). Cow liveweights, body condition scores and blood samples were obtained 3 weeks prepartum, at calving and at 3 and 6 weeks post-partum. The experiment was concluded 6 weeks post-partum. Calf liveweights were recorded at birth and at 3 and 6 weeks.

Housing

The cows were tried in standings in conventional byres with facilities for individually feeding forages and concentrates. At calving the cows were housed in individual loose boxes, calving assistance was given when required and normal husbandry practise was followed including navel spray for calves and udder check for cows. All the calves were confirmed to have suckled well, within the first few hours of life in order to acquire an adequate colostrum intake for provision of energy and passive immunity.

The cows were returned to the byre 3 to 5 days after calving. The calves were tethered immediately behind their dams on a raised, straw covered platform and allowed access to suckle to satiation 2 to 4 times daily.

Diets and feeding

Two dietary treatments were fed to 2 groups of beef cows, each receiving 6 kg FM hay/head/day. Wheat distillers SUPERGRAINS (SG) was one treatment. Twenty

tonnes of undried wheat distillers SUPERGRAINS (SG) was stored and fed to beef cattle over a period of twenty six weeks. The SG was stored in a solid walled enclosure and tightly packed to a settled depth of approximately 1.5m before sealing with a weighed polytene sheet. (Quantities of 250kg of the WDG were kept in a barrow, sufficient for 2-3 days, before weighing and feeding to individual cows).

The other treatment was based upon equivalent dry matter intake with a mixture of equal parts of two proprietary medium-energy concentrate (DCFMIX) feeds intended for use with dairy cows (115g DCP, 9.7 MJ ME).

Treatment 1

During pregnancy one group of cows received 8kg fresh matter SG and 6kg fresh matter hay per cow per day. After calving the amount of SG was gradually increased to 12kg FM per head per day until the end of the trial.

Treatment 2

Two different brands of medium grade commercial dairy concentrate feeds (DCF1 and DCF2) were mixed to provide a suitable comparative diet to SG. This dairy concentrate feed mix (DCFMIX) was fed at 2.58kg FM, together with 6kg FM hay, per head per day during pregnancy. During lactation the amount of fresh matter DCFMIX fed was increased to 3.87kg/head/day. DCFMIX was a complimentary feeding stuff intended to meet the nutritional requirements of pregnant and lactating beef cows given an adequate roughage intake.

The diets were based upon an equivalent dry matter intake per day, during pregnancy all cows received 4.87kg DM hay in addition to 2.224kg DM SG or DCFMIX. During lactation the dry matter intake of SG or DCFMIX was increased to 3.336kg DM/day. Treatment 1, containing SG, however, was supplemented with 100g/head/day of a general purpose mineral supplement (Bowie and Aram Ltd.) during pregnancy and was increased to 200g/day during lactation. The composition of the mineral supplement (g/kg) was Ca 200, P 30, Mg 30, Na 78, and (mg/kg) Cu 1000, Co 100, I 150, Fe 1250, Mn 3000, Zn 3000 and Se 16.

The trial was conducted during the last 10 weeks of pregnancy and first 6 weeks of lactation. For a two week period during late pregnancy an indigestible marker (chromic oxide) was added to the diets in order to carry out digestibility studies.

Feed sampling

Representative feed samples were taken throughout the trial and analysed to determine proximate composition, gross energy value and macroelement content.

Determination of diet digestibility

All the cows received 6kg FM hay/day and 0.5kg FM cubed barley (containing 6.2g/kg DM chromic oxide) was given with the morning feed. One group of cows (Treatment 1) were fed 8kg FM SG/head/day, and the second group (Treatment 2) were fed 2.58kg FM DCFMIX/head/day. Representative feed samples were taken throughout the trial to determine the proximate composition, energy and mineral content (Appendix 2). The trial was conducted over a fourteen day period, preceded by a 3-week period for adjustment to the diet. During the final 7 days of the trial representative faecal 'grab' samples were obtained from each cow, directly from the rectum, (this avoids urine contamination if collected from the floor) at regular intervals, 11.30, 15.30, 23.30, 07.30hr. The samples were bulked for each individual cow and were thoroughly mixed after 7 days collection. Representative subsamples were removed for crude protein determination and proximate analysis and gross energy value (Appendix 2). The digestibility values were determined with regard to total dietary nutrients, Table 4.1 displays the diet compositions. The chromic oxide (Cr_2O_3) marker was supplied in a barley cube form, as previous studies (Crampton and Lloyd, 1951) using sheep, showed more accurate digestibility determinations when small quantities were given in ground feed rather than as chromic oxide powder alone or in capsules as there is more even distribution in the digestive tract.

Blood sampling

10ml heparinised vacutainers were used to collect blood samples from the jugular vein of the cows. The blood samples were analysed to determine the plasma calcium, phosphorus, magnesium and urea concentrations.

RESULTS

Storage and Palatability

Within the first few days of delivery, a surface mould contamination in the uppermost 10-20cm of stored SG was observed. This contaminated layer was discarded because of potential toxic metabolites, compositional changes and the unpalatable nature of the feed. The WDG had a brown appearance and a sticky texture with a pleasant malty odour. The low environmental temperatures helped to preserve the SG as any increases in temperature caused the SG, particularly loose material, to develop an unpleasant odour and some mould contamination.

The SG was generally well accepted by all the cows although the voluntary feed intake of some cows was considerably less than others. This obvious preference for SG was utilised for the purposes of the trial. Those cows showing a preference for SG were allocated to Treatment 1. Towards late gestation some feed refusals were recorded. After calving, the cows allocated to Treatment 1, received increasing amounts of SG, up to a maximum of 12kg fresh matter per day, to meet the increased nutrient requirements during lactation. During the first three weeks post-partum the cows showed a good appetite for SG. By 3-6 weeks post-partum three or four cows showed a loss of appetite for SG (approximately 30% reduction) and associated liveweight loss. This varied from day to day but became a matter of concern with prolonged feeding periods. Three of the eleven cows were withdrawn from the study after showing these detrimental effects in conjunction with a possible mineral imbalance.

Calculation

Digestibility coefficients for each diet were calculated from feed intake and faecal output data (g/kg DM), using the identity:

$$\text{Apparent Digestibility Coefficient} = \left(1 - \frac{[\text{Cr intake}]}{[\text{Cr output}]} \times \frac{[\text{nutrient output}]}{[\text{nutrient intake}]}\right)$$

Table 4.3 describes the supply of nutrients, for pregnancy and lactation, originating from the two dietary treatments and in terms of the recommended daily allowances. (MAFF, 1984; ADAS, 1976) The dietary values were calculated from

the proximate composition and the ME and DCP values for SG and DCFMIX determined from Experiment 3, which are displayed in Table 4.1. SG was considered to contain 249g DCP/kg DM and 14.5 MJ ME/kg DM, DCF1 and DCF2, which formed DCFMIX, were considered to contain 121 and 110g DCP/kg DM and 9.5 and 9.8 MJ ME/kg DM, respectively. These values were calculated using determined DE values from prediction equations. The ME (8.97 MJ/kg DM) and DCP (30.6g/kg DM) values for hay were calculated from MAD fibre and crude protein composition using the prediction equations: -

ME = 16.53 - 0.0213 MADF

DCP = 0.91 X CP - 36.7

Table 4.1 Mean composition of feeds during the sixteen week trial period (g/kg)

	Hay	SG	DCF1	DCF2
No. of samples (n)	8	14	11	11
Dry Matter	812	278	864	852
Dry Matter Composition				
Crude Protein	74	348	173	179
Crude Fibre	361	190	124	112
MAD Fibre	355	275	138	167
Ether Extract	7	88	46	57
N-free Extract	511	355	535	514
Ash	47	19	122	138
Ca	2.88	1.42	15.1	16.8
P	1.48	2.92	7.9	7.2
Mg	0.94	0.61	4.49	4.52
Organic Matter	953	981	878	862
Gross Energy (MJ)	18.0	21.9	17.5	17.4
ME (MJ) +	9.0	14.5	9.5	9.8
DCP ++	31	249	121	110

\+ ME values calculated from DE values determined in Experiment 3, and from MAD Fibre content for hay (ME = 16.53 - 0.0213 MADF)

++ DCP values determined in Experiment 3 and from crude protein content for hay (DCP = 0.19 X CP - 36.7)

The recommended daily allowances, shown in Table 4.3, for DCP are met by Treatment 1 (SG) for pregnancy and lactation. Both dietary treatments contained insufficient ME to meet the full requirements for a lactating cow, and Treatment 2 (DCFMIX) did not contain sufficient ME to meet the demands for ME during pregnancy. Treatment 1 (SG) was deficient in dietary magnesium during pregnancy

and lactation and the consequences of this, with regard to animal production, are discussed later. Both dietary treatments contained considerably less phosphorus than the recommended allowances, for pregnancy and lactation.

Table 4.2 Mean digestibility coefficients determined for total diets using beef suckler cows during pregnancy

	Treatment diets including hay.			
	Treatment 1 (SG)		Treatment 2 (DCFMIX)	
	Mean	SE	Mean	SE
Dry Matter	0.584	0.013	0.572 NS	0.006
Crude Protein	0.574	0.019	0.470 NS	0.012
Organic Matter	0.582	0.010	0.588 NS	0.007
Gross Energy	0.572	0.014	0.560 NS	0.009
Crude Fibre	0.545	0.018	0.506 NS	0.008

Significance levels, relative to SG

NS Not significant.

No significant differences were detected between the two dietary treatments due perhaps to the common factor of 4.38kg DM daily intake of hay.

Table 4.3 Apparent metabolisable energy, digestible crude protein and macro-mineral content of the two dietary treatments (g/day) and the recommended dietary allowances (g/day) during pregnancy and lactation

Supply of nutrients for pregnant 500kg cows 7 weeks pre-partum	Treatment 1 (SG*)	Treatment 2 (DCFMIX)	Recommended Dietary Allowances**
ME MJ/day	76	65	74
DCP	704	405	495
Ca	37	48.5	51.2+
P	16.6	23.1	58.9+
Mg	9.0	14.5	12.1+
Nutrient supply for 500kg cow producing 10 l milk/day			
ME MJ/day	92	76	112
DCP	980	532	825
Ca	58.5	66.0	53+
P	22.7	31.3	45+
Mg	12.8	19.6	15+

* Includes G.P. mineral supplement, (200g Ca, 30g P, 30g Mg/kg). 100g/d during pregnancy and 200g/d during lactation.

** MAFF (1984), ADAS (1976)

\+ ADAS (1983)

Cow liveweight change and calf growth rate

Twenty two cows were observed during pregnancy but during the calving period some five cows were withdrawn from the trial. One cow receiving Treatment 1 (SG) suffered a prolapsed uterus following parturition and died. One cow receiving Treatment 2 (DCFMIX) gave birth to a dead calf. A second cow receiving Treatment 2 (DCFMIX) was given an intravenous administration of calcium borogluconate, within eight hours of calving, after showing symptoms of hypocalcaemic tetany and recovered to normality.

At calving each cow and calf were housed in a loose box for 3 to 5 days to develop a strong maternal attraction. All the calves suckled well, within the first 4 hours of life, to provide maximum capacity for acquired immunity from immunoglobulin absorption from colostrum. Further aspects will be covered in Section III. Within the first 3 weeks of life one calf developed a mild pneumonia and Eschericia coli infection. Veterinary treatment was given in the form of a neosulphentrin bolus, but a number of other calves developed symptoms and had a reduced liveweight gain. This may have been accentuated by the close proximity of calves to one another and the restricted access to suckling, relative to normal suckling behaviour patterns. (Selman, 1969)

Three cows receiving Treatment 1, containing SG, began to lose appetite and displayed symptoms of hypocalcaemia and hypomagnesaemia. These health and metabolic problems of cows and calves required some of the experimental data to be excluded from the final analysis, due to their abnormal condition.

Table 4.4 shows the significant differences detected, using the statistical t-test, for cow liveweight change during the trial. At the end of the trial (6 weeks post-partum) the seven remaining cows receiving Treatment 1 (SG) were compared with the seven cows with which they were originally paired, at 10 weeks before calving, shown in Table 4.5. Using comparisons for only seven cows provides mean values which are more appropriate than comparing different sized groups of cows. The mean liveweight loss, for the six week period post-calving was similar for both groups, 34kg for cows receiving DCFMIX and 33kg for cows receiving SG. The calf growth rate was slightly higher (0.97kg/day) for cows fed DCFMIX than for cows fed SG (0.86kg/day).

Both groups of cows showed a loss in body condition during lactation. The stress conditions imposed during pregnancy and lactation were overcome nutritionally by feeding SG, or DCFMIX as the major source of metabolisable energy, and at transfer to grass the cows rapidly achieved a satisfactory body condition before the remating period with a view to next years production.

Table 4.4 Mean cow liveweights (kg), body condition scores and calf liveweights (kg) during the trial period

weeks before (-) or after (+) calving		Treatment 1 (SG)			Treatment 2 (DCFMIX)		
		n	$\bar{x}$	sem	n	$\bar{x}$	sem
cow liveweights	- 10	11	502	12.15	11	497	14.62
	- 3	11	533	9.77	11	515	12.8
	0	10	494	12.21	10	480	13.63
	+ 3	9	450	11.67	10	453	13.03
	+ 6	7	472	17.08	10	443	14.04
Body score	- 10	11	2.4	0.17	11	2.4	0.18
	- 3	11	2.6	0.16	11	2.3	0.11
	+ 0	10	2.5	0.17	10	2.5	0.09
Calf liveweights	+ 3	9	2.5	0.13	10	2.4	0.11
	+ 6	7	2.5	0.20	10	2.3	0.12
Calf birthweights liveweights	+ 0	10	48.3^{+}	1.94	10	41.8	1.94
	+ 3	9	69.0 NS	2.70	10	63.0	2.60
	+ 6	7	83.0 NS	3.63	10	79.1	3.29

Table 4.5 Mean values obtained when the remaining seven cows, fed diet 1 (SG) are compared with the cows receiving DCFMIX with which they were originally paired, 10 weeks pre-partum

Weeks after calving		Diet 1		Diet 2	
			SG		DCFMIX
		$\bar{x}$	sem	$\bar{x}$	sem
cow liveweight (kg)	0	505	15.6	490	18.9
	3	470	11.9	464	17.1
	6	472	17.1	456	18.3
Body condition score					
	0	2.7	0.16	2.5	0.08
	3	2.5	0.5	2.4	0.12
	6	2.5	0.20	2.4	0.13
calf liveweights (kg)	0	47.4	2.4	41.4	2.3
	3	68.9	3.5	64.9	3.1
	6	82.9	3.6	82.1	4.2

Concentration of blood metabolites

Table 4.6 describes the mean values for plasma metabolite concentrations for cows given each dietary treatment. When the treatment diets were formulated both represented commercial farm diets and Treatment 1 was supplemented with a general purpose mineral mix. Table 4.3 shows the quantities of mineral actually supplied by each diet and the mineral requirements for cows during pregnancy and lactation.

Table 4.6 Plasma metabolite concentrations (mmol l^{-1}) for eleven cows given each dietary treatment during the trial period

weeks before (-) or after (+) calving		Treatment 1 (SG)			Treatment 2 (DCFMIX)		
		n	$\bar{x}$	sd	n	$\bar{x}$	sd
Urea	- 10	11	5.84	1.47	11	4.68	1.44
	- 3	10	7.54^{NS}	1.82	11	3.83	0.97
	0	10	11.97***	3.70	10	6.25	1.90
	+ 3	9	9.09***	1.38	9	5.84	0.28
	+ 6	7	7.06***	2.37	10	3.63	0.54
Ca	- 10	11	2.11	0.10	11	2.11	0.06
	- 3	10	2.14	0.05	11	2.13	0.10
	0	10	2.26	0.16	10	2.22	0.15
	+ 3	9	2.29	0.24	9	2.33	0.14
	+ 6	7	1.99	0.31	10	2.06	0.12
P	- 10	11	2.29	0.30	10	2.39	0.26
	- 3	11	1.93	0.24	11	2.24	0.30
	0	10	1.52	0.27	10	1.65	0.25
	+ 3	9	2.27	0.23	9	2.54	0.34
	+ 6	7	2.26	0.45	10	2.30	0.33
Mg	- 10	11	0.66	0.10	11	0.67	0.08
	- 3	10	0.66	0.09	11	0.71	0.07
	0	9	0.67^{NS}	0.13	10	0.74	0.07
	+ 3	9	0.55***	0.20	9	0.74	0.09
	+ 6	7	0.32***	0.13	10	0.64	0.08

Significance levels from direct comparison of treatments.
NS not significant
* P < 0.01, ** P < 0.05, *** P < 0.001

Blood calcium and phosphorus concentrations were measured throughout the experiment as these two macroelements have important physiological functions during pregnancy and lactation. Repartitioning of these nutrients during stress periods is critical and a slight imbalance can induce metabolic disorders.

During pregnancy the plasma metabolite concentrations for cows receiving either treatment were normal and very similar except that cows given SG appeared to have higher plasma urea concentrations. At calving the plasma phosphorus concentrations dropped to 1.52 mmol l^{-1} and 1.65 mmol l^{-1} for Treatment 1 and Treatment 2 respectively as nutrient partitioning occurs immediately prior to the onset of lactation. By 3 weeks post-partum the plasma phosphorus concentrations had returned to the previous normal levels and by 6 weeks they had increased even further.

The raised levels of circulating urea, after calving, in the blood of cows receiving Treatment 1 (SG) (11.97 mmol l^{-1}) were significantly different from those cows receiving Treatment 2 (6.25 mmol l^{-1}) and reflects the higher dietary protein intake from SG.

The mean plasma calcium concentrations during the trial were close to the normal range of values (Underwood, 1981). One cow receiving Treatment 1 (SG) had a plasma calcium concentration of only 1.3 mmol l^{-1} at 6 weeks post-partum in addition to a low plasma magnesium concentration (0.16 mmol l^{-1}).

At 3 and 6 weeks post calving the mean plasma magnesium concentrations for cows receiving Treatment 1 (SG) were significantly lower than for those receiving Treatment 2. Individual cows given SG showed extremely low values (0.09 mmol l^{-1} at 3 weeks) and 0.16 and 0.18 mmol l^{-1} at 6 weeks. One cow collapsed at 5 weeks post-partum and showed symptoms of hypocalcaemia and hypomagnesaemia. Veterinary treatment was given but a total loss of appetite contributed to the death of this cow. The plasma concentrations, at 3 weeks, for this cow were; Ca 2.24 mmol l^{-1}, P 2.45 mmol l^{-1} and Mg 0.44 mmol l^{-1}. One cow receiving Treatment 1 (SG) was withdrawn from the trial at 3 weeks post-partum (plasma Mg 0.09 mmol l^{-1}) and another cow also receiving Treatment 1 was given an intravenous administration of magnesium and calcium borogluconate solution.

DISCUSSION

This production trial, using beef suckler cows, was based upon equivalent dry matter intakes for both treatments. Dry matter was the factor chosen as the nutrient composition of the novel by-product (Wheat distillers SUPERGRAINS) was unknown, when the experiment commenced. The production process influences the final structure and composition and consequently, the nutrient availability. The inclusion of a general purpose mineral supplement was intended to meet the requirements for Ca, P and Mg of pregnant and lactating cows when given more normal diets.

This study has shown SG to be a source of high energy and protein, containing significant amounts of digestible carbohydrate. The by-product was easily stored and fed to cows which showed a good appetite and voluntary feed intake.

Table 4.1 describes the nutrients supplied in each dietary treatment. The recommended dietary allowances for pregnant and lactating cows are shown in Table 4.3 together with the dietary nutrient supply in terms of ME and DCP. The DCP intake of the cows, fed SG, exceeded the recommended allowances and perhaps compensated for the ME intakes, which were lower than the recommended values for pregnant (74 MJ/day) and lactating (112 MJ/day) cows. The cow liveweight loss, post-partum, was approximately 0.8 kg/day, which is higher than normally expected, but considering the lack of dietary ME is a compensatory mechanism equivalent to 0.8 x 14 = 11.2 MJ ME to overcome the shortfall to energy values for ME and DCP of hay (proximate composition g/kg DM CP 74, CF 361, MADF 355, Ash 46, GE 18.1 MJ) were calculated using prediction equations: -

$$ME = 16.53 - 0.0213\ MADF$$

$$DCP = 0.91\ X\ CP - 36.7 \quad \text{(MAFF, 1984)}$$

From these values and those for SG and DCFMIX the apparent nutritive value of dietary treatments is displayed in Table 4.3, in comparison to the recommended daily intakes of ME and DCP for a 500kg cow during pregnancy and lactation.

Table 4.2 gave the apparent digestibility values for total diets and it can be concluded that SG is a suitable alternative to proprietary feed compounds in terms of its digestible nutrients and metabolisable energy content SG may be a potential concentrate feed for beef suckler cows when an appropriate mineral supplement is given, which should contain more magnesium than was given here. This experiment is based upon the assumption that the digestibility of SG remains the same for mature animals, at any stage of production, and that digestibility values determined in sheep are the same as that for cows. The high protein content of SG caused an increased catabolism of amino acids by rumen micro-organisms and the consequences of this are elevated concentrations of circulating urea. It is expected that the salivary urea levels would also be increased, as would the ammonia levels both in the rumen and liver. The efficiency of the microbial population and physiological requirements for amino acid synthesis determine the fate of elevated urea levels. Any urea which is not utilised is excreted in the urine.

Lactation exerts a physiological demand upon the metabolism of the body and the elevated blood urea concentrations also indicate a response to this demand, as breakdown of urea to form amino acids provides precursors for milk protein synthesis by the mammary gland. Protein requirements are given in terms of DCP as originally recommended by ARC (1965). Recent workers Miller (1973), Roy et al. (1977) have influenced the recommended allowances (ARC, 1980, 1984) to redefine ruminant nitrogen requirements as being N required by the animal and N required by the rumen microbial population, CP = RDP + UDP. The extent of ruminal protein degradation is limited by the rumen environment and by the nature of the feed, in terms of the quantity, quality, structure and associated feeds.

Another factor which increases the protein content of SG, and the effective DCP available, is the presence of yeast within the by-product. During distillation and subsequent centrifugation, to produce SG, yeasts are present in the material. The yeast is an important component of this novel by-product feed. Gray and Ryan (1990) reported the effects of feeding yeast cultures, to sheep receiving a roughage diet. The ruminal investigation results they obtained indicated that yeast reduced the pH of rumen fluid and elevated VFA production. An increased rumen bacterial population also contributed to an increased production of high quality protein. Barber and Lonsdale (1980) also observed that high quality fermenter yeasts have

been fed successfully to ruminants and improved the digestibility of protein. The high oil content of SG may cause some proteins to be protected from rumen digestion. The composition of the oil fraction may ultimately affect the fat composition in muscle tissue or milk, with regard to the amount of saturated fatty acids.

The consequences of feeding excess protein in a diet may induce nutritional imbalances and affect the composition of body tissues. Further aspects of excess protein in ruminant diets is discussed in Experiment 5. Feeding very high levels of protein may depress the voluntary feed intake, and is wasteful of protein.

Even although supplementary minerals were supplied there was insufficient magnesium, in the diet containing SG, to meet the recommended allowances (ADAS, 1983) for pregnancy and lactation. The high oil content of SG (88g/kg DM) may also have contributed to hypomagnesaemia by reducing the available magnesium and calcium for absorption (Miller, El Hag and Pratt, 1970). Magnesium deficiency symptoms are induced by a stress factor, such as cold, wet weather, and exacerbated by the age and condition of the cow.

The dietary phosphorus requirements during pregnancy and lactation are also under supplied in both dietary treatments. At calving there was a noticeable drop in blood phosphorus concentration and it may be suggested that this could be an imposed metabolic stress factor inducing symptoms of magnesium deficiency. The use of blood magnesium concentrations for predicting cases of hypomagnesaemia when the concentration falls below 0.4-0.5 mmol/litre is a useful criterion. The trial, however, was not designed to induce magnesium deficiency and except for trials of this nature it is important to ensure adequate amounts are supplied in the diet, or blood magnesium concentrations be measured at frequent intervals. It is concluded that an increased amount of supplementary magnesium should be given in diets containing SG.

The reduced feed intakes and loss of appetite in cows post-partum associated with hypomagnesaemia may be caused by the metabolic disorder, or the feed refusals may contribute to reduced magnesium intakes. Parker (1989) also observed similar effects when feeding barley draff (malt distillers grains) with only 0.64g Mg /kg DM

plus straw and was forced to abandon the study because of continued feed refusals and hypomagnesaemic cows. If the voluntary feed intake is a problem, regardless of magnesium supplementation, further studies need to be performed to examine the possible loss of rumen function, in terms of motility, microbial population energetics and end-products of digestion.

The storage effects have not been investigated in this trial. When the SG was delivered, direct from the distillery the material was still extremely warm, and continued to be warm for some weeks due to continued fermentation. Although the proximate analysis showed relatively little variation, the quality and composition of specific nutrients may change over a period of time.

The high copper concentration of SG (144mg/kg DM) obviously indicates this to be an unsuitable sole feed source for sheep, but prolonged use of SG as a feed for cattle may also produce, as yet unforseen, side effects. There are possible effects during foetal development, or as toxic metabolites accumulations inducing liver damage.

When using SG as a commercial feed the possible benefits of feeding of high protein feed may be exploited by feeding a supplementary low quality source of roughage, eg. straw. Equally, a reduced amount of SG could be given with barley to maintain ME intake.

For a commercial enterprise livestock are normally group-fed and individual feed refusals of SG would be hard to monitor, so sufficient intake must be ensured, either by stimulating appetite by feeding soluble carbohydrates or by restricted access to feed, rather than an ad-lib system. The results obtained have effectively shown that the feeds were comparable and that either one could have been as a sole feed source for the purposes of this trial. The relative costs of the feeds used, on a dry matter basis, were £201/tonne DCFMIX and £95/tonne SG. During the trial the feeds were fed on an equivalent dry matter basis with supplementary minerals being added to SG. This production trial has shown SG to be a more cost effective feed for beef suckler cows during pregnancy and lactation than DCFMIX. The relative production gains achieved by feeding barley and soya may not enable SG to be fed as an alternative to these feeds.

EXPERIMENT 5 WHEAT DISTILLERS SUPERGRAINS (SG) AS A FEED SOURCE FOR LACTATING DAIRY COWS

INTRODUCTION

This study investigated the nutritional effects of feeding SG to dairy cows in terms of milk yield and milk composition.

The basal diet of silage, available ad-libitum, was assessed using sheep in metabolism crates (Experiment 5a) to determine the apparent digestibility and nutritive value.

The production trial which was conducted throughout the winter months compared the milk production performance when cows were given either SG or malt distillers grains (MDG). Previous work (Experiment 3) using sheep described these feeds in terms of their proximate composition and nutritive value.

Experiment 5(a) Determination of the digestibility of silage

MATERIALS AND METHODS

A detailed description of the experimental procedures performed for apparent digestibility determination are explained in Experiment 1.

Feeds and feeding

The cows were given access to the face of a silage clamp, where the daily intake was restricted using electrified fencing. The silage was made from first-cut grass with an added silage inoculant to promote lactic acid. A 300kg sample of silage was taken from the centre of the clamp face and the exposed silage discarded. A fresh, moist sample free from surface contaminants was stored in sealed drums before weighing and feeding to sheep. 2.5kg ($\pm$ 10g) fresh matter silage was fed daily to each sheep in two feeds. Any feed refusals were recorded to provide an accurate record of feed intake.

Animals and Management

Six wether sheep, mean liveweight 42.2kg were housed in metabolism crates during the trial. Accurate measurements were made of the feed intake and the total faecal output was collected over a seven day period.

Feed Sampling

Representative feed samples were taken throughout the trial period and analysed to determine the proximate composition and gross energy value.

RESULTS

The silage was generally well consumed by the sheep but some refusals and spillages were weighed and analysed to accurately determine the dry matter intake.

Table 5.1 describes the proximate composition of the silage. It was a good quality silage, 20% dry matter and 16% crude protein content. The ash determinations showed some variation, which was attributed to soil contamination.

Calculation

The apparent digestibility values were determined using the identity:

$$\text{Apparent digestibility} = \frac{\text{Total [nutrient] Intake - Total [nutrient] Output}}{\text{Total [nutrient] Output}}$$

[ ] refers to dry matter, organic matter, gross energy, crude protein, crude fibre.

The results are shown in Table 5.1 together with the calculated values for DCP, ME and DOMD.

Table 5.1. Proximate composition and apparent digestibility coefficient determined for silage.

	g/kg DM	Apparent Digestibility coefficient
Dry Matter g/kg	207	0.73
Crude Protein	162	0.73
Crude Fibre	264	0.79
Ether Extract	44	ND
Ash	100	ND
NFE	430	ND
OM	900	0.76
Ca	2.68	ND
P	4.68	ND
GE	18.1	0.73
DE	13.18	
DCP	115	
DOMD	685	
ME	10.96 (DOMD% X 0.16)	
	10.7 (DE X 0.81)	(MAFF, 1984)

Experiment 5(b) Milk production for cows given SG or MDG

MATERIALS AND METHODS

Animals and experimental design

A dairy herd of some 70 British Friesian and British Friesian/Holstein cows were used in an examination of the milk yields and compositions produced from the feeding of either malt distillers grains (MDG) or wheat distillers SUPERGRAINS (SG) as components of the basal diet.

The trial consisted of a multiple changeover design where all the cows in the herd, irrespective of stage of lactation, received either MDG or SG in successive feeding periods throughout the winter. Each cow thus acted as its own control and further comparisons of mean yields and composition performance during each feeding

period were enhanced by the use of a covariance analysis used to correct the effect of time on yield persistence.

For that purpose a preliminary period of three weeks commenced in October 1989 when a basal ration calculated to supply maintenance and production of the first 15 litres of milk (M + 15) was given and individual milk yields and composition recorded.

The experiment consisted of three periods I, II and III and ran over a 24 week period from November 1989 to April 1990. Within each were two equal time periods when either MDG or SG were given as components of a basal diet designed to supply the requirements for M + 15. The outline design giving dates and feeds given during the trial is shown below:-

Experimental design showing feeding periods, duration and the number of cow data sets used for the three statistical analyses (A, B and C).

			Cows in each analysis		
Period	Weeks	Feed	A	B	C
I	1-4	MDG	14	21	24
	5-8	SG			
II	9-11	MDG	14	21	28
	12-24	SG			
III	15-19	MDG	14	-	24
	20-24	SG			

Dietary treatments

The composition and nutritional values of feeds given during the trial are detailed in Table 5.2. The basal ration given to all cows in each of the three feeding periods was grass silage (ad-libitum), 10 kg MDG or SG and 4 kg molassed sugar beet pulp. This was calculated to supply the nutrient requirements for maintenance and the production of the first 15 litres (M + 15) of milk (Table 5.3). The nutrient requirements of cows producing over 15 litres of milk per day was supplied by the provision of 0.4 kg/l of a standard commercial compound preparation, given individually in the milking parlour.

Table 5.2 Composition of feeds (g/kg DM) in diets of dairy cows given malt distillers grains (MDG) or Supergrains (SG) during experimental period.

	Silage	SBP	Conc+	MDG	SG
Dry matter	204	873	860	247	280
Crude protein	157	108	175	212	351
Digestible Crude Protein	115	61	110	152	250
Crude fibre	252	146	125	223	186
Ether extract	40	4	46	82	95
N-free extract	416	646	532	448	349
Ash	135	96	122	35	19
Organic Matter	865	904	878	965	981
Calcium	4.5	12.1	14.8	1.3	1.3
Phosphorus	2.8	0.85	8.1	3.8	3.0
Copper (mg)	ND	ND	ND	16.4	144
Gross Energy MJ/kg DM	17.6	16.5	17.6	21.0	22.2
Digestible Energy MJ/kg DM	13.2	13.6	11.8	13.8	16.4
Metabolisable Energy MJ/kg DM	10.7	10.7	9.8	11.4	13.6

ND not determined

\+ Standard commercial dairy concentrate

Table 5.3 Mean dietary allowances for dairy cows given either MDG or SG

kg Fresh matter	kg DM	MJ ME	g DCP
35 Silage (ad-lib)	7.0	75	805
10 MDG / SG*	2.5/2.8	28/38*	381/697*
4 SBP	3.5	37	214
Totals	13.0/13.3	140/150*	1400/1716*
Requirements for M + 15 milk		138	1165

*SG was shown (from metabolism evaluation) Experiment 3 to contain more ME and DCP than MDG although similar fresh quantities were on offer during the dairy trial.

Milk recording and analyses

The milk yield of each cow was recorded every seven days. The daily yield of each cow was recorded from the content level of a graduated milk jar (Alfa Laval) after each of two successive milkings at 05.30 and 15.30 h. Samples were taken at each milking and combined for the later analyses of fat and protein content (Scottish Milk Marketing Board Central Testing Laboratory) using an infra-red analysis technique (Milkoscan 300, Foss Electric Ltd.).

RESULTS

Analyses of results

Data was collected from every cow in milk during the whole of the experiment. However data from cows which were less than 40 days calved or yielding less than 20 l/d at the start of any recording period and that of sick cows were eliminated from the statistical calculations.

Three separate data sets were collated and analysed: -

(A) Data from 14 selected cows which successfully completed all three experimental Periods I, II and III. Each cow had been calved not less than 40 days and not longer than 140 days at the beginning of the trial and had completed the preliminary covariance period.

(B) Data from 21 selected cows which fully completed Periods I and II which thus included all 14 cows from data set (A) together with an additional 7 cows which had been calved longer than 180 days at the start of Period I.

(C) Data from all cows in the herd which were eligible for inclusion in each of the three separate feeding periods. These totalled 24, 28 and 24 for Periods I, II and III respectively. The cows comprising this data set thus included the 14 cows of (A) in each period together with the additional 7 cows included in (B) in Periods I and II only. The remainder of the cows in each set included more recently calved cows (but over 40 days in milk) whose records were complete for each individual feeding period.

Both the malt distillers grains (MDG), which was supplied from Dumgoyne Distillery and the Cameronbridge wheat distillers SUPERGRAINS (SG) were well consumed by all the cows. The draff was available to the cows in a feeding passage after the morning milking and the allocation was generally all consumed by midday.

Initially there was some storage loss of SG as a result of surface moulding, sometimes to a depth of 10cm. This material was discarded.

The cows ate the SG material with obvious relish and the estimated consumption rate was estimated to be 35-50% faster than for an equal ration of MDG.

Milk recording and sampling were performed weekly. However on one occasion in early January (week 8) the weather was particularly bad and evening milking on that day was very early. The yields on that single occurrence were consequently lower than usual. The data has not been corrected to compensate for this and mean values for the first feeding period when SG was given are undoubted reduced as a result. It is possible to apply a correction, however the results presented here are as recorded.

Analysis A

Mean yields and composition data of the milk of the 14 cows which completed all three single changeover feeding periods I, II and III are given in Table 5.4. Also included are covariance adjusted estimates where the group yield persistency was used to calculate mean yields as if the two draff treatments were given at the same time thus removing the natural effect of yield decline with stage of lactation. It is not possible to fit acceptable errors to the adjusted data.

Weekly mean milk yields and outputs of fat and protein are depicted graphically in Figs. 5.1 and 5.2. Mean milk yields and fat/protein yields for each of the treatment feeding periods are shown in Figs. 5.3 and 5.4. Examination of the adjusted yield data in summary shows over the whole winter period fully comparable performance results for both MDG and SG with a tendency for an increase in both the total fat and protein yields when SG was given.

Table 5.4 Mean yields and composition (including standard error) of the milk of 14 cows given MDG and SG in successive feeding periods throughout the whole experiment. (Analysis A).

Period	Feed	Yield kg	SE	Bf%	SE	Protein%	SE	Fat kg	SE	Prot kg	SE
I	MDG	21.8	0.61	3.650	0.083	3.22	0.067	0.804	0.0247	0.696	0.0200
	SG	20.8	0.53	3.740	0.089	3.23	0.064	0.774	0.0238	0.686	0.0186
II	MDG	20.1	0.65	3.610	0.090	3.30	0.069	0.720	0.0241	0.656	0.0211
	SG	19.3	0.64	3.440	0.080	3.30	0.078	0.662	0.0233	0.632	0.0203
III	MDG	17.9	0.52	3.490	0.080	3.22	0.060	0.622	0.0204	0.578	0.0161
	SG	17.4	0.58	3.530	0.074	3.44	0.064	0.611	0.0218	0.540	0.0185

Mean yields adjusted by covariance*

Period	Feed	Milk kg	Fat kg	Protein kg/d
I	MDG	22.0	0.803	0.708
	SG	22.3	0.834	0.720
II	MDG	20.4	0.736	0.673
	SG	19.9	0.684	0.657
III	MDG	18.0	0.628	0.580
	SG	18.3	0.646	0.630

Replicate block analysis of variance (adjusted data)

	Milk	Fat	Protein (kg/d)
MDG	20.13	0.722	0.653
SG	20.17	0.721	0.669
Pool SD	2.010	0.094	0.057

* Adjusted [using data from pre-trial period] such that the natural effect of yield decline with time is removed and treatment means recalculated as if they had been received simultaneously.

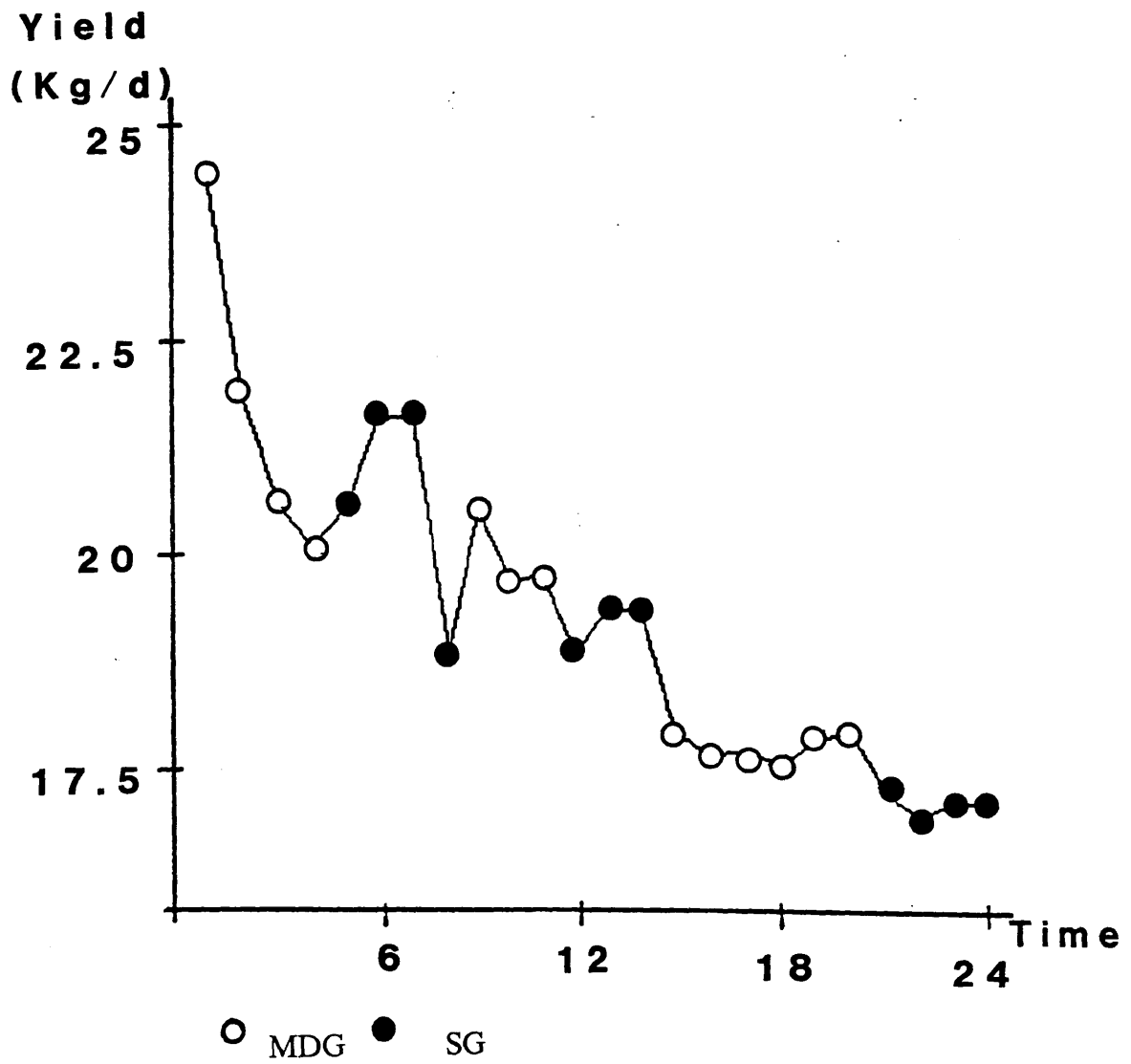


Figure 5.1 (Analysis A) Mean weekly milk yields of 14 cows in all three periods.

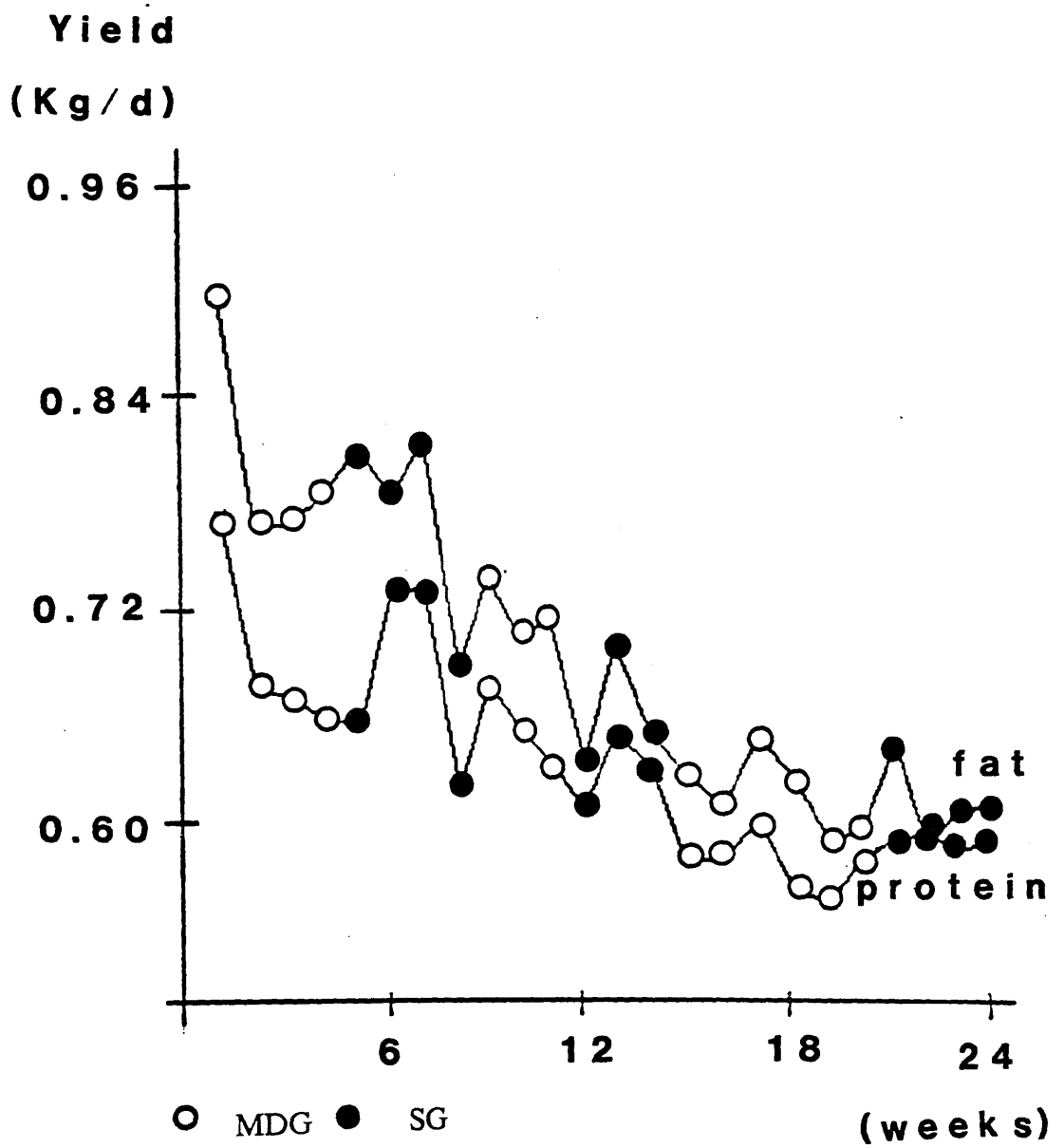


Figure 5.2 (Analysis A) Mean weekly fat and protein yields of 14 cows in all three periods.

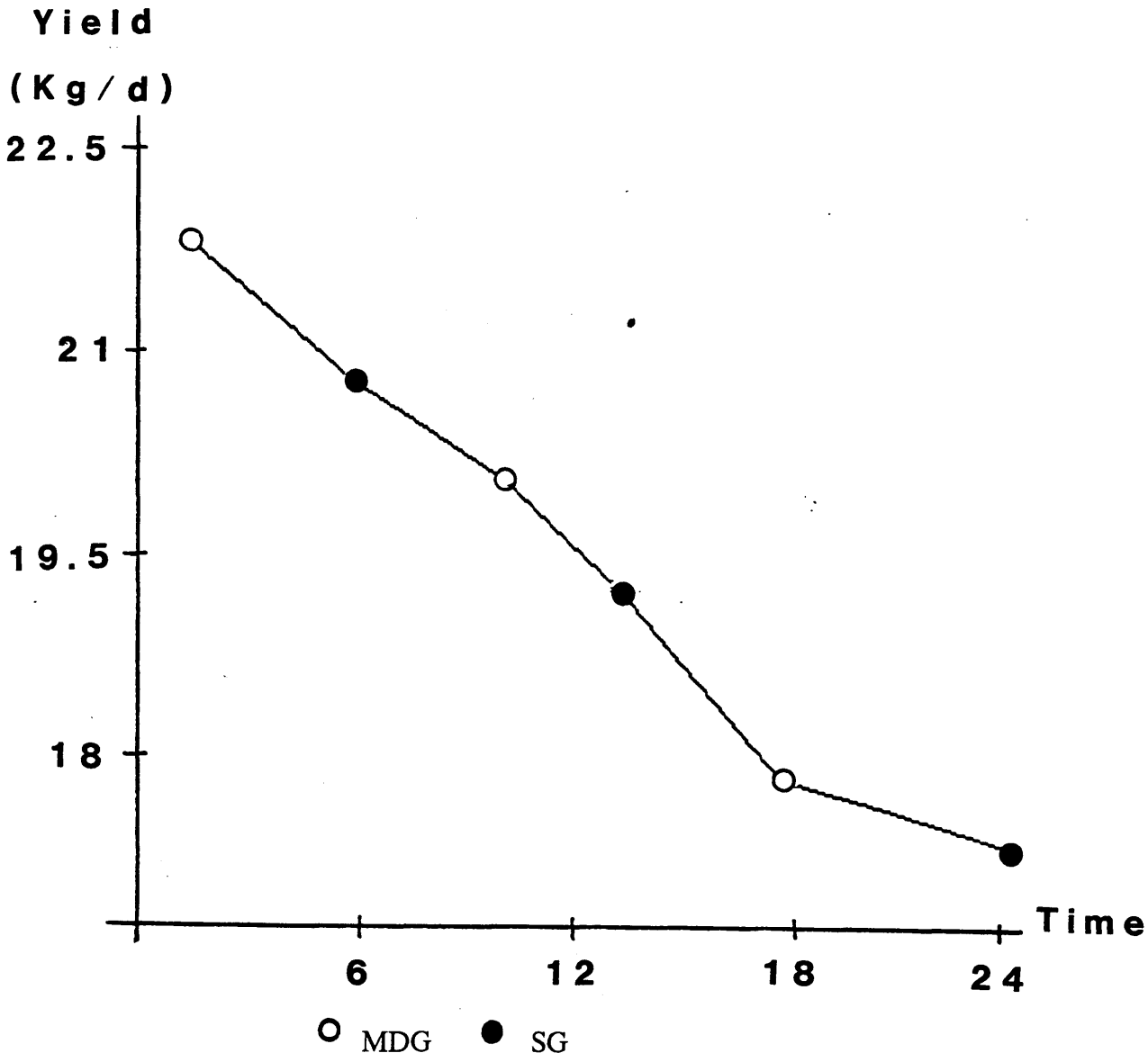


Figure 5.3 (Analysis A) Mean milk yield of 14 cows in all three periods.

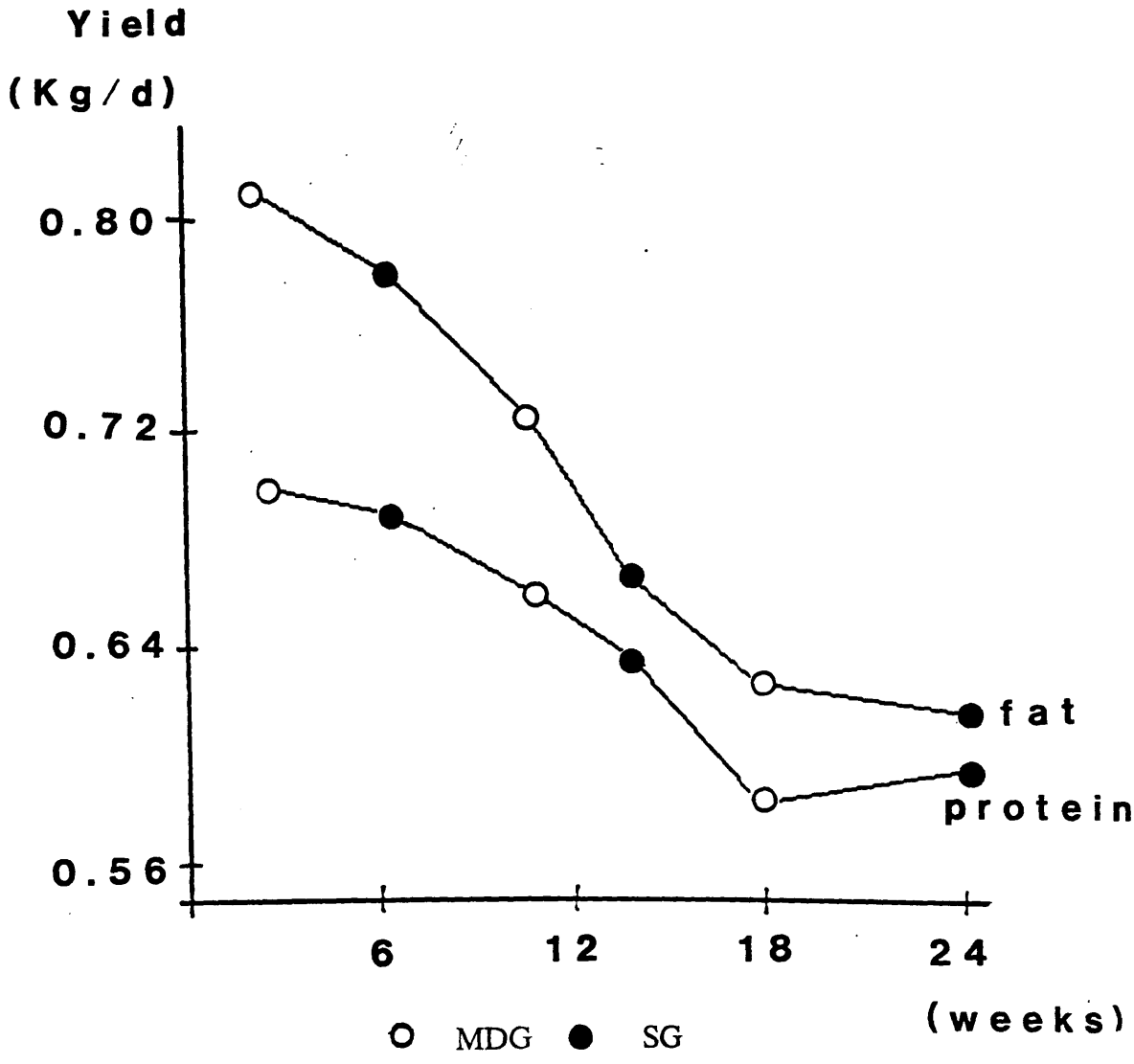


Figure 5.4 (Analysis A) Mean fat and protein yields of 14 cows in all three periods.

Analysis B

Similar results sets are given for the 21 cows which completed the feeding Periods I and II completely in Table 5.5 and in Figs. 5.5, 5.6, 5.7 and 5.8. The results promote similar observations on the production characteristics associated with the treatment periods. This is largely because 14 of the 21 cows are common to the analysis set (A) described above and include a further 7 cows which were later in lactation and were not eligible for inclusion in Period III.

Table 5.5 Mean yields and composition (including standard error) of the milk of 21 cows given MDG and SG in successive feeding periods I and II. (Analysis B).

Period	Feed	Yield kg	SE	Bf%	SE	Protein%	SE	Fat kg	SE	Prot kg	SE
I	MDG	21.6	0.44	3.71	0.065	3.24	0.046	0.800	0.0190	0.696	0.0149
	SG	20.1	0.39	3.78	0.066	3.33	0.044	0.758	0.0180	0.668	0.0136
II	MDG	19.0	0.50	3.63	0.076	3.33	0.054	0.686	0.0188	0.629	0.0156
	SG	18.1	0.52	3.51	0.062	3.35	0.055	6.330	0.0190	0.599	0.0158

Mean yields adjusted by covariance*

Period	Feed	Milk kg	Fat kg	Protein kg/d
I	MDG	21.7	0.805	0.703
	SG	21.8	0.824	0.726
II	MDG	19.0	0.690	0.633
	SG	18.9	0.663	0.632

Replicate block analysis of variance (adjusted data)

	Milk	Fat	Protein	(kg/d)
MDG	20.35	0.748	0.668	
SG	20.40	0.744	0.679	
Pool SD	2.018	0.099	0.059	

* Adjusted [using data from pre-trial period] such that the natural effect of yield decline with time is removed and treatment means recalculated as if they had been received simultaneously.

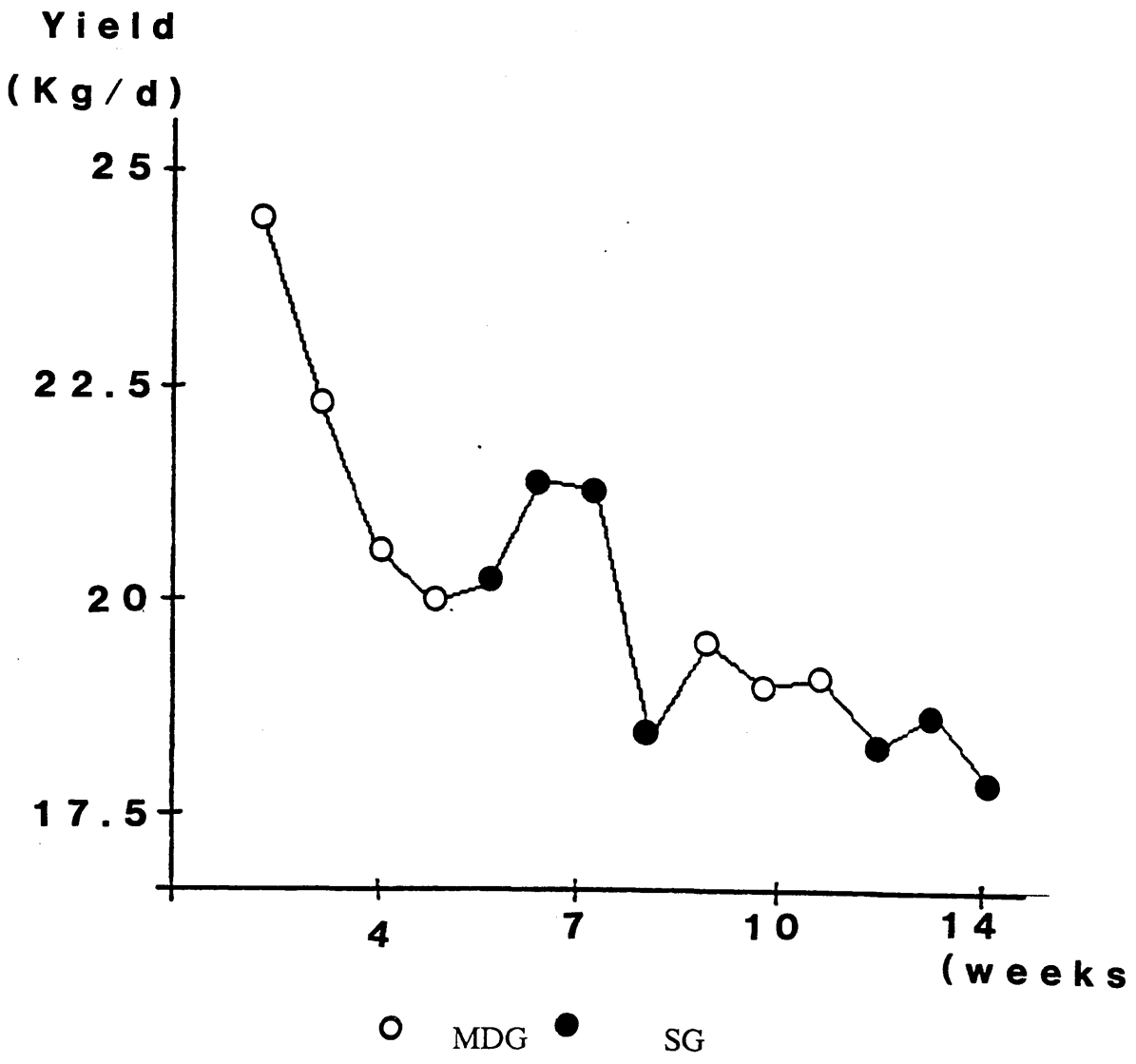


Figure 5.5 (Analysis B) Mean weekly milk yields of 21 cows in period I and II

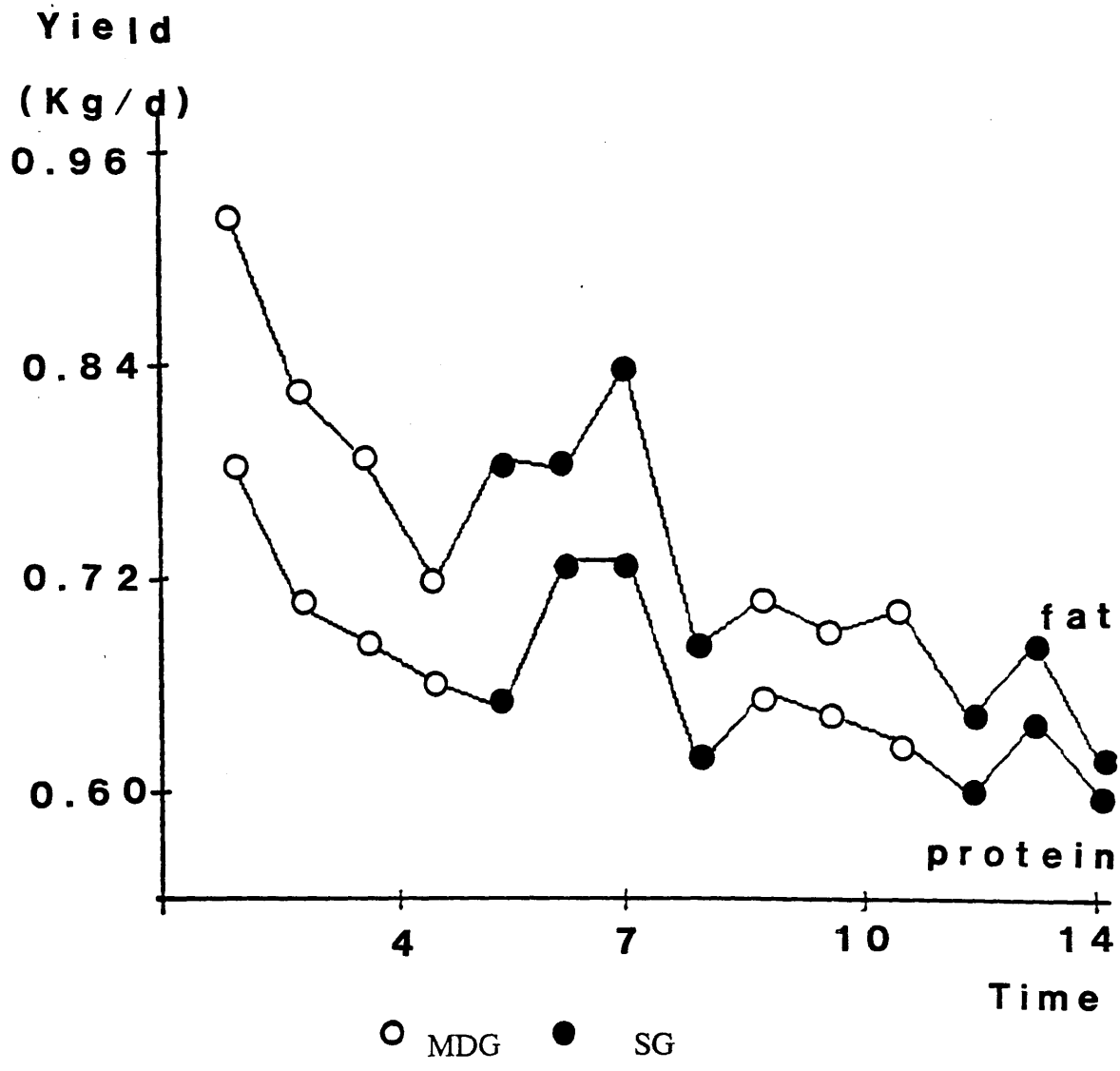


Figure 5.6 (Analysis B) Mean weekly fat and protein yields of 21 cows in periods I and II

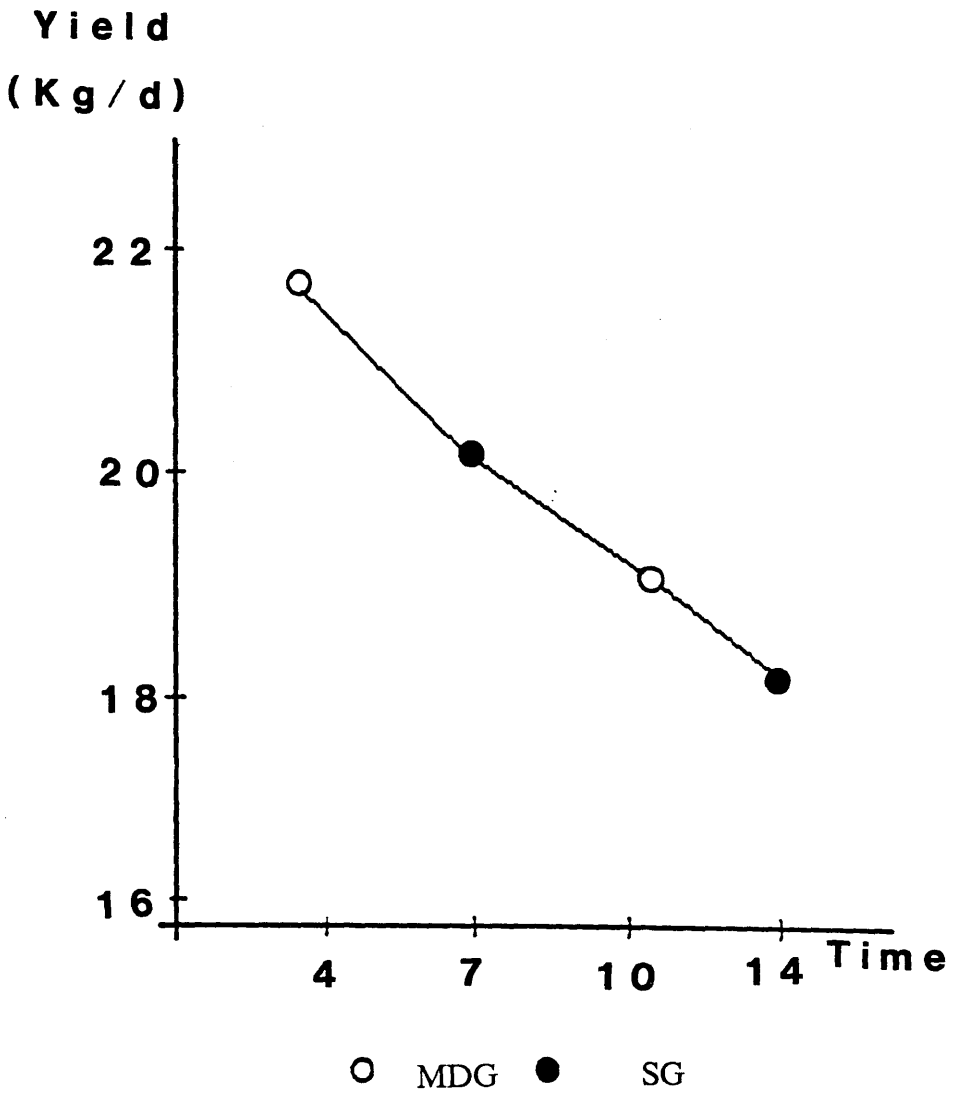


Figure 5.7 (Analysis B) Mean milk yield of 21 cows in periods I and II

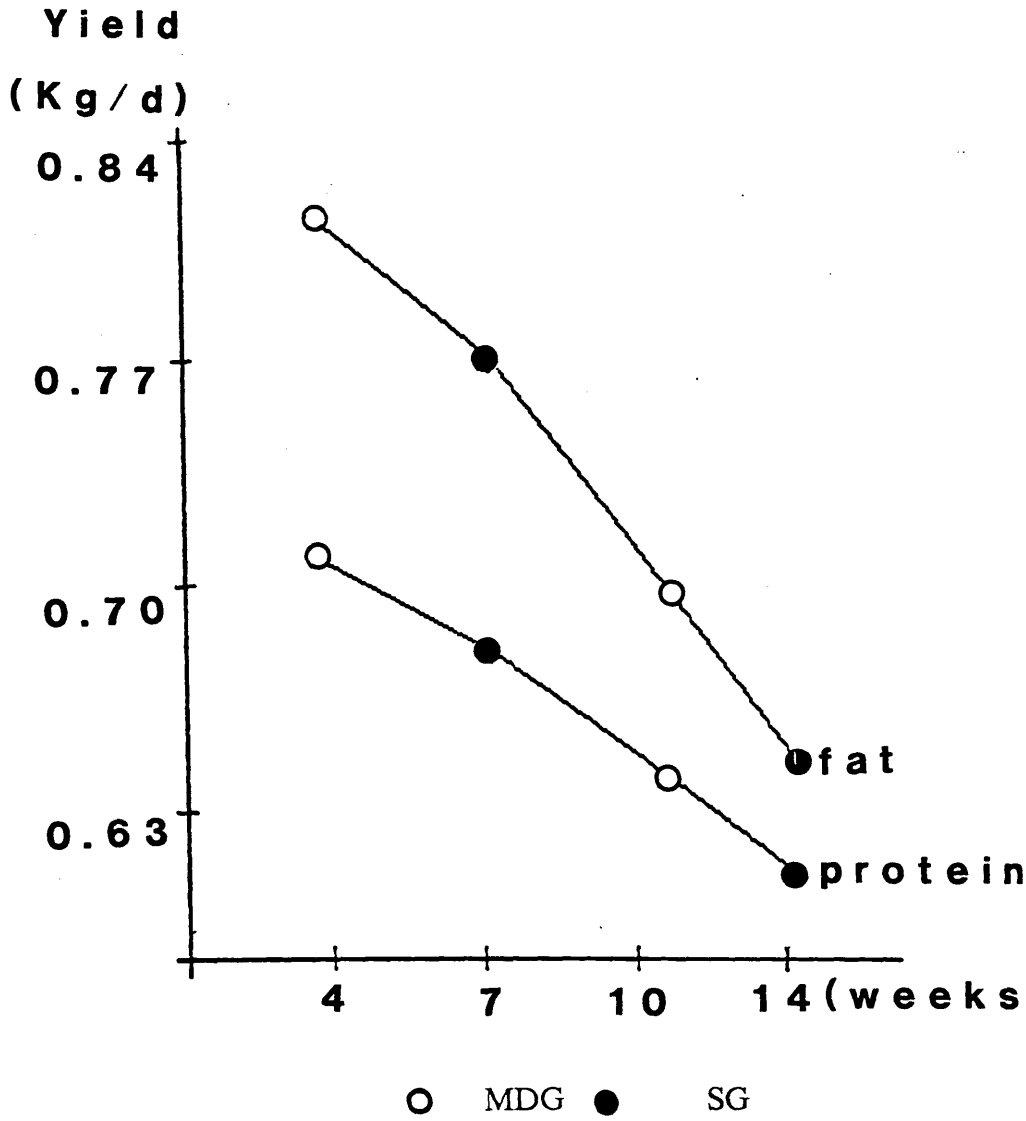


Figure 5.8 (Analysis B) Mean fat and protein yields of cows in periods I and II

Analysis C

Results from the assessment (C) can be best regarded as three separate single changeover experiments which ran consecutively over the winter. In this analysis the continuous 14 cows of (A) plus the 21 cows of (B) are included together with more recently calved cows in each of Periods II and III.

The standard mean yield and compositional data is presented in Table 5.6 and graphs for the whole winter are given in Figs. 5.9, 5.10, 5.11 and 5.12.

In all the data sets it is noticeable that the rapid persistency decline observed in the first MDG treatment period was quickly reversed by the subsequent SG treatment. (The unusual records obtained for week 4 of this SG period unfortunately reduces the mean for the whole treatment period by 0.95 kg/d in the adjusted values, i.e. mean milk yields for Period I would then be: - MDG 22.0 and SG 23.2kg/d).

On further inspection of the covariance adjusted mean data for each analysis set these results can be regarded as replicate blocks and the analysis of variance calculated is included separately in each of the Tables 5.4, 5.5 and 5.6. The pooled standard errors are large here since only the meaned values from each period (adjusted by covariance) were used and not individual cow data. Nevertheless it is quite clear that there were no apparent differences in the production parameters when either distillers grains or Supergrains were given to any of the animal groupings used for evaluation.

Table 5.6 Mean yields and composition of the milk (including standard error) of all cows given MDG or SG during the three winter feeding periods. Analysis C.

Period	Feed	Yield	SE	Bf%	SE	Protein%	SE	Fat kg	SE	Prot kg	SE
I	MDG	21.1	0.416	3.75	0.0594	3.30	0.045	0.785	0.0174	0.688	0.0138
	SG	19.2	0.432	3.81	0.0600	3.42	0.044	0.728	0.0184	0.648	0.0135
II	MDG	20.7	0.592	3.67	0.0640	3.30	0.044	0.757	0.0239	0.675	0.0173
	SG	20.4	0.693	3.51	0.0530	3.32	0.046	0.713	0.0245	0.667	0.0200
III	MDG	21.8	0.615	3.53	0.0570	3.22	0.039	0.771	0.0244	0.694	0.0177
	SG	21.3	0.642	3.61	0.0520	3.39	0.042	0.768	0.0250	0.712	0.0244

Mean yields adjusted by covariance*

Period	Feed	Milk kg	Fat kg	Protein kg/d
I	MDG	21.4	0.802	0.706
	SG	20.6	0.785	0.865
II	MDG	20.9	0.767	0.690
	SG	21.2	0.744	0.704
III	MDG	22.2	0.784	0.715
	SG	22.0	0.794	0.746

Replicate block analysis of variance (adjusted data)

	Milk	Fat	Protein (kg/d)
MDG	21.50	0.784	0.704
SG	21.27	0.774	0.772
Pool SD	0.679	0.023	0.060

* Adjusted [using data from pre-trial period] such that the natural effect of yield decline with time is removed and treatment means calculated as apparently being received simultaneously.

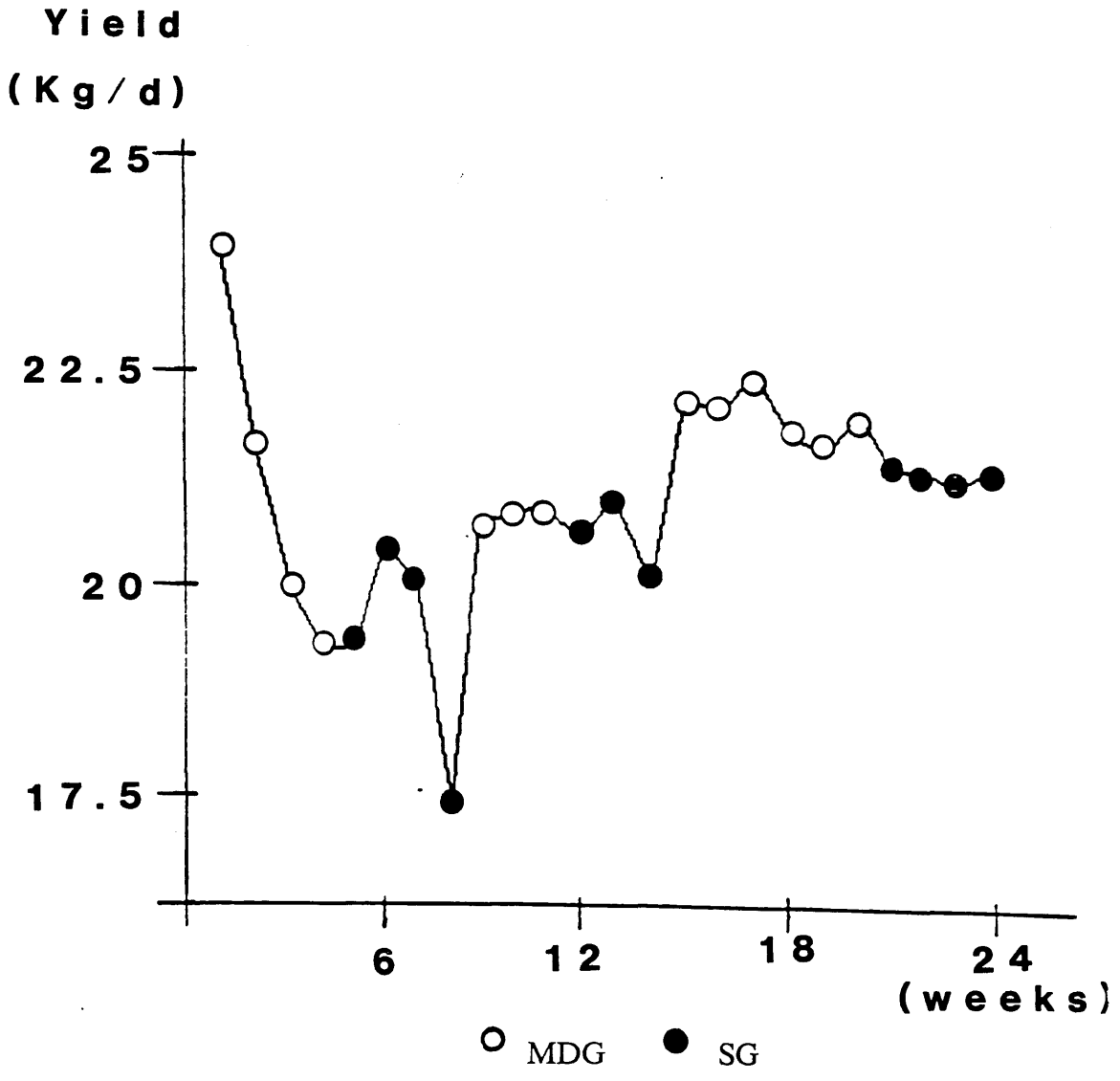


Figure 5.9 (Analysis C) Mean weekly milk yields of all cows in all three periods (24 weeks)

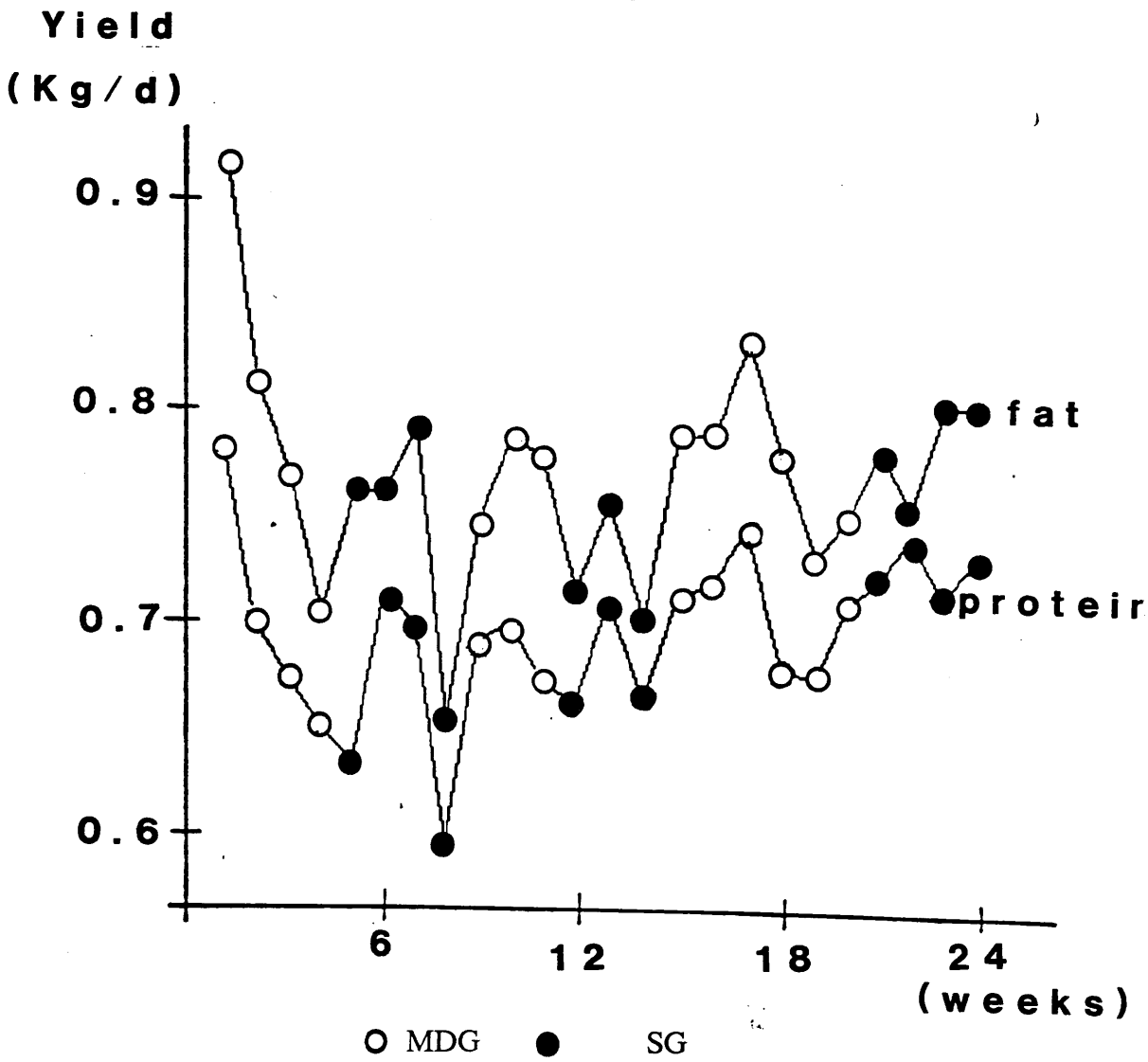


Figure 5.10 (Analysis C) Mean weekly fat and protein yields of all cows in all three periods

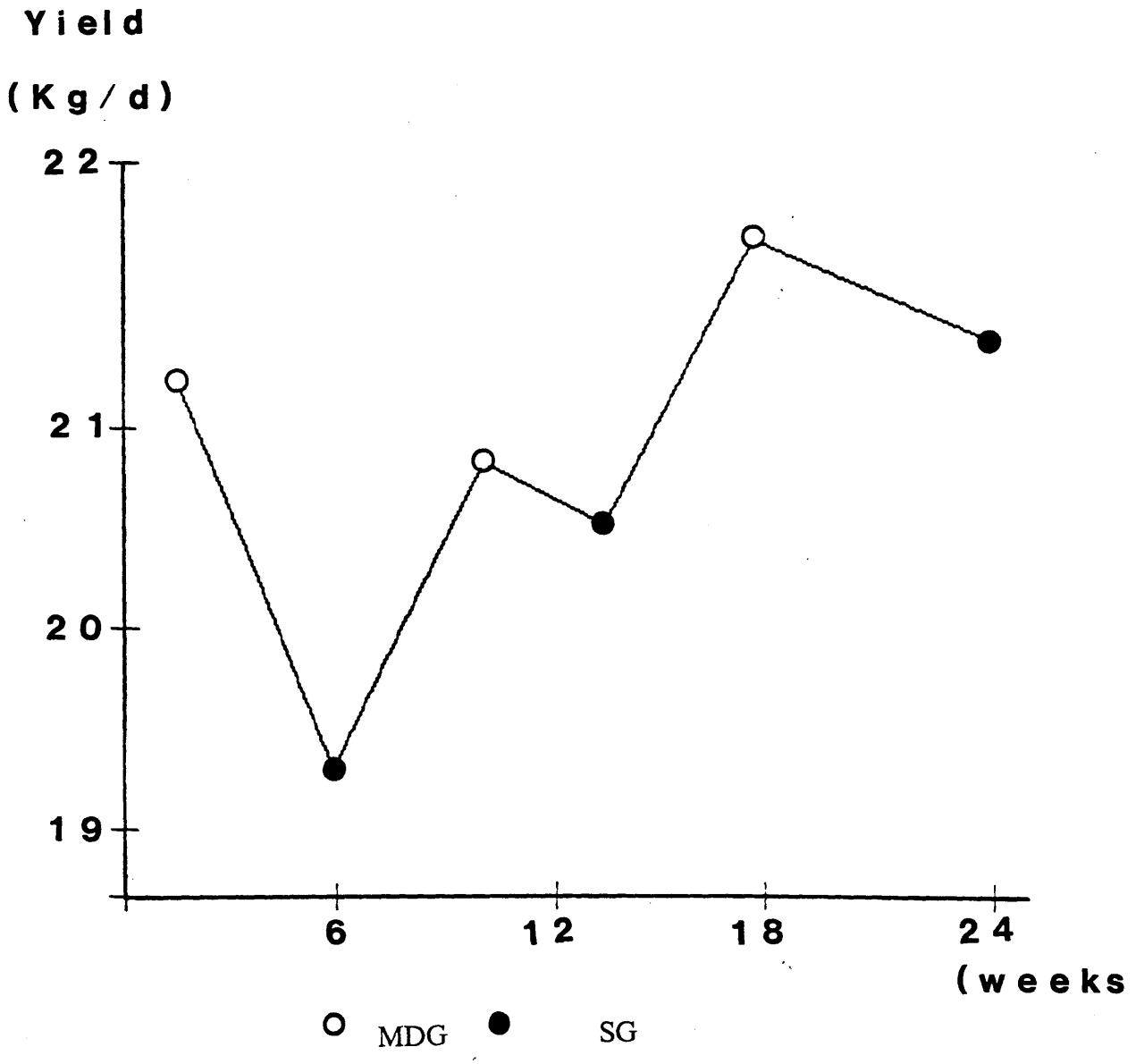


Figure 5.11 (Analysis C) Mean milk yields of all cows in all three periods

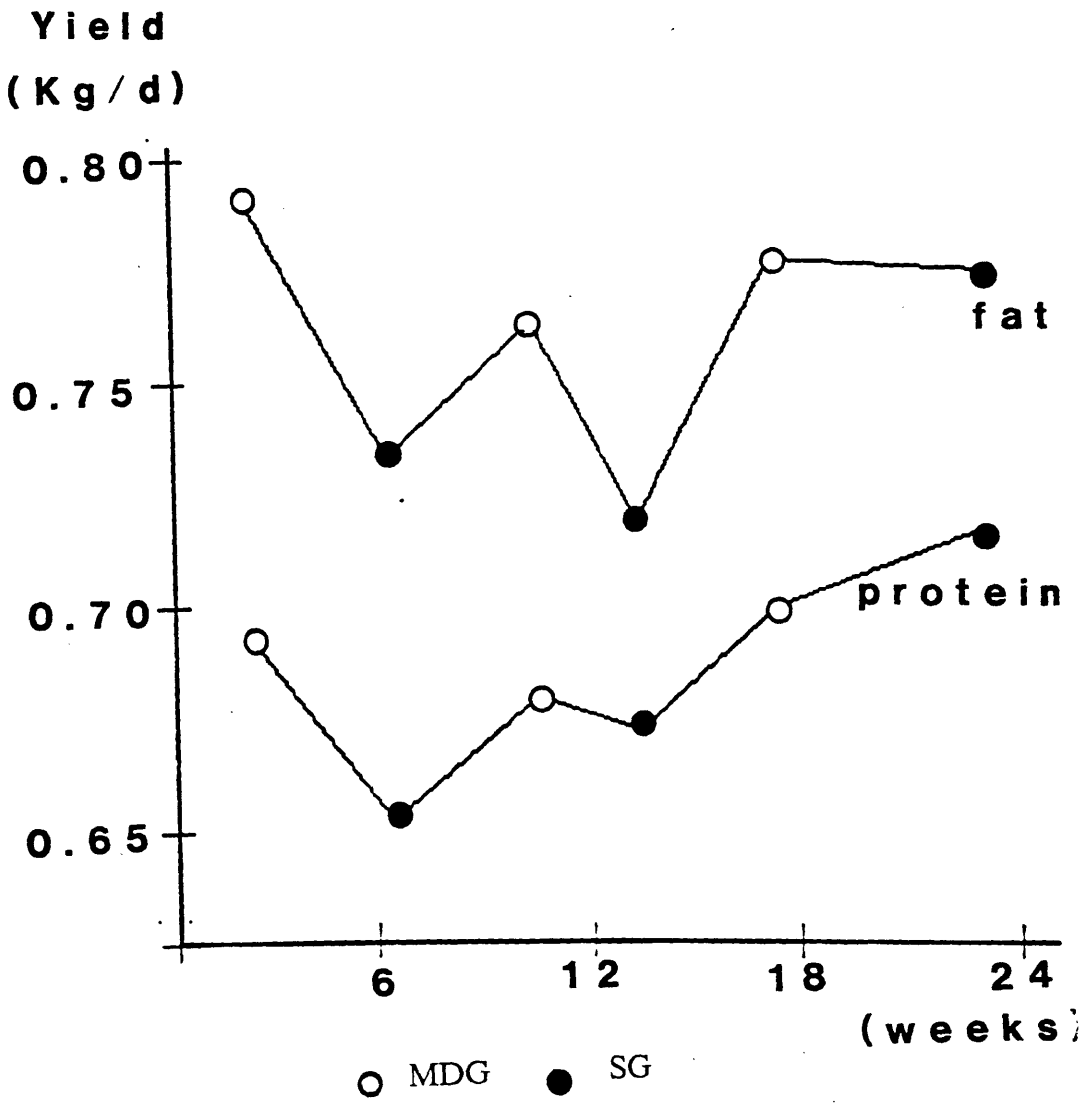


Figure 5.12 (Analysis C) Mean weekly fat and protein yields of all cows in all three periods

DISCUSSION

A constraint in the experimental design was that the feeding arrangements and milking practises of the commercial farm unit did not permit division of the herd to allow both feeds to be given to separate balanced groups of cows at the same time. Thus the two different materials were given to the whole herd in a common feeding passage in alternate feeding periods during the housed winter period.

The silage was highly digestible and was shown to be a good source of metabolisable energy (10.7 MJ/kg DM) and digestible crude protein (115g/kg DM). The values compared favourable with typical values for good quality silage of 10.2 MJ ME/kg DM, 116g DCP/kg DM (MAFF, 1984) and 10.7 MJ ME/kg DM, 105g DCP/kg DM, 665g DOMD/kg DM (MAFF, 1986). It was assumed that the silage was equally digestible for dairy cows as it was for sheep.

In the circumstances describes here where good quality silage was freely available together with a ration of 10kg either MDG or SG and 4kg SBP for the production of the first 151 milk, the feeds produced entirely comparable results.

The basal rations (Table 5.3) both supplied excess digestible protein for M + 15 (235 and 551g in surplus for MDG and SG respectively), but this would be a normal situation where these materials are used and due attention needs to be given on the correct balanced concentrate to be recommended in such diets. This is particularly so with respect to the mineral supply as the total ash contents of distillery by-products is very low. This is reflected however, in the high gross energy of SG (Table 5.2) ash 19g and GE 22.2 MJ/kg DM).

The results of this experiment confirm the adequacy of the calculated requirements for maintenance and milk production when the ration containing MDG was compiled. At the outset of this trial an equal DM weight equivalent of SG was given. In the event, SG was shown in a separate metabolism evaluation (Experiment 3), to contain about 70% more digestible crude protein content (250 and 152g DCP/kg DM for SG and MDG respectively) and considerably high Metabolisable Energy (ME) being 13.6 and 11.6 MJ ME/kg DM for SG and MDG respectively. This can be also compared to a value of 9.8 MJ ME obtained for the

commercial dairy concentrate. It would be interesting to test the equivalence value of SG to a standard malt draff experimentally in more nutritionally restricted circumstances since calculation shows 1kg DM SG to be equal to 1.2kg DM MDG on an energy basis but also supplying 100g DCP more than MDG at that replacement rate.

Taylor and Parkins (1989) described the nutritional values of certain new distillery by-products and discussed the findings of Wainman et al., (1984) in respect of distillery feeds. It was noted that the greater ME value for wheat centrifuge cake (ex - Port Dundas) being produced at that time (13.1 compared to 9.5 MJ ME/kg DM for malt draff) was attributable to both higher gross energy contents and also a considerably increased digestibility coefficient (0.70 compared to 0.56). The wheat distillers SUPERGRAINS was determined as having an ME of at least 13.6 MJ/kg and a DCP of 250g/kg DM.

It is speculated that in the trial described the cows were unable to respond in milk production output to the increased energy and protein intakes from the SG treatment as the nutrient supply was already adequate. It is likely that this may have resulted in an increase in bodyweight during these feeding periods. The animals were not weighed during the course of the work and further trials with a controlled group or individual feeding should make provision for this.

SECTION III

IMMUNOLOGICAL STATUS OF THE NEONATAL RUMINANT.

BACKGROUND REVIEW

Immune System

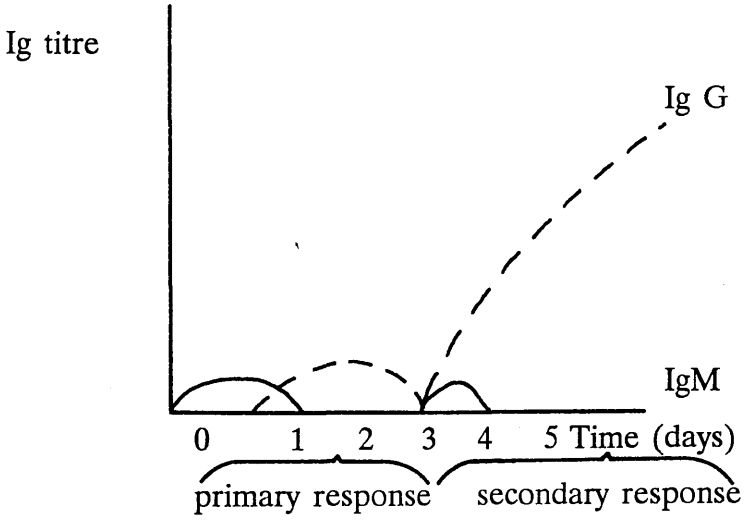
The mammalian body is susceptible to infection and disease by foreign invading antigens. Specialised methods have evolved, as part of the immune system, to counter-attack and prevent invading antigens from entering the body. The adaptive immune response of the body involves the production of lymphocytes which respond specifically to foreign antigens by activation and clonal proliferation. These lymphocytes are responsible for humoral and cell-mediated responses. Surface receptors on some of the lymphocytes are protein structures of four polypeptide chains. These specific receptor proteins are known as immunoglobulins. The immunoglobulins play a defensive role by reversibly binding to invading antigenic material through non-covalent interactions. Each polypeptide chain which comprises an immunoglobulin contains a variable sequence of amino acids which confers the specificity of the particular immunoglobulin and the constant amino acid backbone sequence directs the activity of the immunoglobulin (Roitt, 1984).

There are five major classes of immunoglobulin (Ig) which have been identified and the structures and functions defined. Approximately 10% of the circulating immunoglobulin occurs as IgM. This immunoglobulin initiates the primary immune response by intravascular activity and causes bacterial agglutination. IgA amounts to 15-20% of circulating immunoglobulin. IgA is also secreted by plasma cells in the submucosa of the respiratory, intestinal and urinary tracts and in the interstitial regions of the mammary gland. IgA provides passive protection against intestinal pathogens by coating the lumenal surface of gut mucosal cells in neonates. (Wernet et al., 1971; Porter and Allen, 1972) The IgA concentration in ruminant colostrum is much lower than for non-ruminants to allow development and establishment of rumen microflora. IgD, less than 1% of total immunoglobulins, acts mainly as a surface antigen receptor for B-lymphocytes. IgG is the major immunoglobulin in bovine colostrum, (70-75%), and plays a major role in the secondary immune response. It has extravascular activity and has chemotactic properties for phagocytes. IgE, less than 1% of total immunoglobulin, plays a major role in atopic

allergy reactions and defence against parasitic infection. In conjunction with circulating mast cells and basophils IgE stimulates granule release and induces lysis of invading micro-organisms.

The sites of synthesis for immunoglobulins are the central compartments of the immune system (blood and lymph) and also localised sites for IgA and IgE. Immunoglobulins circulate in the blood and originate from passive and acquired transfer. Passive transfer occurs during foetal development and from immunoglobulins ingested in the colostrum. Acquired immunity is achieved by the stimulation of Ig and lymphocyte production from challenges by invading antigens. The challenges by invading antigens initiate two types of response. The primary immune response induces virgin lymphocytes, which exist in the peripheral lymph to develop into effector cells which counter attack in the antigen. The response is relatively slow and only minimal amounts of specific lymphocytes and immunoglobulins are produced. Some of the virgin lymphocytes also develop specifically into memory cells. When the animal is exposed to a second challenge by the same antigen the memory cells produce a rapid response and proliferation of active cells to form the secondary immune response (Figure 3.0).

Figure 3.0 Immunoglobulin titre against time (days)



The exposure to foreign antigens and penetration of infectious and pathogenic micro-organisms relies on the response of the immune system mechanisms to prevent the animal from succumbing to the challenging antigen. Acquired

immunoglobulin status commences when an animal is 4 to 6 weeks of age, although there is time variation between species. Prior to acquired immunity, the neonatal animal is dependant upon the immunoglobulins achieved by passive transfer from maternal origin.

Many species can confer immunological status to the developing foetus via uterine and placental blood transfer. Young humans, primates and rabbits have developed an in utero acquisition of IgG, whilst ungulate species derive all immunoglobulins from the colostrum alone (Butler, 1974). Dogs, cats and the majority of rodents possess a two stage mechanism for achieving immunoglobulin status, transfer in utero and from colostrum immunoglobulin.

Colostrum

During late pregnancy the non-diffusible constituents of blood plasma are concentrated in the mammary gland. Hypogammaglobulinaemia in pre-partum serum has been shown to occur in cows (Dixon, 1961) and Paape and Pearson (1975) reported a significant reduction in cow serum immunoglobulin at parturition. Colostrum is the 'first milk' and has a different composition to milk. Colostrum can be obtained from pre-partum milking (Hill, Widdowson and Maggs, 1950) and immediately post-partum. Variation in milk composition due to species difference is also evident for colostrum composition.

The major common factor which differentiates between colostrum and milk is an increased protein content, attributed to the immune proteins (immunoglobulins). In bovine species there is an increase in carotene, fat soluble vitamins and total dry matter content (Roy, 1980). The fat content remains high but variable and increased protein and mineral concentrations are at the expense of lactose.

Colostrum also contains alpha and beta lactalbumin and a range of enzymes, including lactate and malate dehydrogenase and xanthine oxidase which is prominent in bovine milk.

The placenta of the ruminant animals is impermeable to protein. In consequence immunoglobulins are acquired by neonatal ruminants through the ingestion of

colostrum which also provides energy and acts as a laxative. The immunoglobulins are protected from proteolysis in the pre-ruminant gut by an elevated pH and are absorbed directly into the epithelial cells.

Innate Immunity

The immunoglobulin system for defense against disease is known as the adaptive response. The innate immune response is dependant upon physical barriers, soluble factors (interferon, lysozyme) phagocytes and specialised leukocytes (neutral killer cells). Within the alimentary tract there are digestive enzymes, organic and inorganic acids, symbiotic microflora, bile salts and mucins (Porter and Barratt, 1987). The mechanical influences of peristalsis and gut evacuation also have an effect on immunoglobulin transfer.

The multifacet role of colostrum is still not fully explained, but it is believed to form an integral function in the protection of the gut itself. Colostrum may have a prophylactic role by protecting the epithelium against colibacillosis (Logan, 1974) but has no benefit once diarrhoea starts.

Immunoglobulin transfer and absorption

The majority of work concerning colostrum intake, and transfer of immunity in cattle, has been reported for dairy cows and calves, eg. Brignole and Stott, 1979; Edwards and Broom, 1982; Selman, McEwan and Fisher, 1971. Selman (1969) suggested that newborn calves should ingest 3-4 litres of colostrum (70ml/kg liveweight) in order to achieve satisfactory serum immunoglobulin concentrations. Ingestion should be within the first four hours of birth, especially in poor environmental conditions. Transfer and absorption of immunoglobulins from the intestine to the blood system occurs only within the few first hours of life, up to 24 hours (Pierce, 1955). Peak serum immunoglobulin concentrations are generally observed 24 hours after suckling (Logan, Penhale and Jones, 1972; Logan, McBeath and Lowman, 1974).

Determination of adequate immunological status in calves can be obtained from blood serum analysis. Critical immunoglobulin levels for calves have been reported by Prior and Porter (1980) to be 12mg/ml IgG and by Logan (1980) to be 20 ZST

(zinc sulphate turbidity) units, which is an estimation of the total immunoglobulin concentration.

Despite the critical levels described and advice from the British Veterinary Association (1985) on the health of young animals many problems are still encountered concerning neonatal disease of farm animals. Many authors have reported (Gay, 1965; Smith and Halls, 1968; Ingram and Malcolmson, 1970) that the quality and quantity of colostrum ingested was not invariably reflected in the serum immunoglobulin levels of calves. Simpson-Morgan and Smeaton (1972) reviewed the transfer of immunoglobulins and described the factors which affect the rate of intestinal transfer. Immunoglobulin transfer from the small intestine is by micropinocytosis into the columnar epithelium (Clark, 1959) and is a non-selective process. Penhale et al. (1973) reported a differential rate of absorption of the individual immunoglobulins, IgG 90%, IgM 59% and IgA 48%. The apparent lack of immunoglobulin status of calves, identified by low serum Ig levels may be due to morphological changes of the gut mucosa or due to the digestive substances present in the gut after a period of time.

In addition, it has been suggested that serum Ig concentrations themselves may not be a direct reflection of the immune status of the animal.

Ducker and Fraser (1976) reported the importance of allowing lambs to have access to colostrum within the first six hours of birth. The importance of adequate colostrum intake in the health of newborn lambs has been described by Halliday (1978) and suggested adequate colostrum intake to be 30ml/kg liveweight. Ducker and McEwan (1972) described the use of the zinc sulphate turbidity test for determining immunoglobulin concentrations in neonatal lamb sera. Sheep immunoglobulin status and transmission in the neonatal has been reviewed in detail by Campbell, Siegel and Knowlton (1977) and Eales (1987) stressed the prophylactic role of colostrum for the prevention of watery mouth in young lambs.

Husbandry and suckling behaviour

Selman et al. (1971) described the variation in serum immunoglobulin concentrations of newborn dairy heifer calves. Traditional husbandry management

methods of calving "in the field" highlighted the benefit of prolonged grooming and suckling in relation to achieving high serum Ig concentrations, mean value 24.4 ZST units. Logan (1980) considered that serum Ig concentrations, in calves, above 30 ZST units would be adequate for good health and immunity. Studies by Selman (1970) described the effects of the age of the cow on calf access to suckling. Heifers and very young cows had sensitive udders and actively hindered suckling. Older cows tended to be more passive, but as age increased the tendency to lie down was increased and prevented calf access to the udder. This effect was also noted by Edwards and Broom (1979) especially for recumbent dams, eg. those which were hypocalcaemic. Also, calves may encounter difficulties with initially locating the teats of cows with pendulous udders.

A report by Ducker and Fraser (1973) described the benefits of intensive management of ewes and lambs at parturition. The assessment of viable lambs, ensuring lambs were properly dried, ensuring ewe milk let-down and housing in individual pens contributed to the intensive level of husbandry. There was a significant effect on the quantity of immunoglobulin absorbed, particularly by twin lambs, and the rapid establishment of ewe/lamb relationship in the absence of interference from other animals. Further studies by Ducker and Fraser (1976) described the importance of housed lambs being given a first suck of colostrum within six hours of birth to obtain low lamb mortality, high serum Ig concentrations and subsequent high growth rate.

Artificial milk and colostrum supplements

Commercially produced milk substitutes (replacers) were originally developed for feeding to dairy calves. The formulation of such a product is required to reflect the characteristics of natural cows milk.

The milk replacers should allow the formation of a milk clot in the abomasum of the calf due to the action of chymosin (rennin) enzyme. Clot formation facilitates the initial digestion of fat and casein by lipolytic and proteolytic enzymes. Stobo (1983) described in detail the chemical composition and characteristics of artificial milk replacers for calves. Separated (skimmed) milk and vegetable fat is recommended as a suitable feed for pig production systems, due to the high energy

value and good quality protein (MAFF, 1983). These milk substitutes are formulated from excess milk production which cannot be utilised by the dairy industry to produce products for human consumption. There is a large trade in calf milk replacers which are manufactured as dried milk powders and which require reconstitution before feeding.

Recently in the farming press, there has been information regarding novel commercial products designed to improve the health of the young animal. Ritchie (1989) described a natural antibody supplement for calves which had been developed in America. This commercially available product is reported to contain natural antibodies extracted and concentrated from milk whey without harming their immune function. As the whey is derived from a colostrum pool it is claimed to provide a broader spectrum of antibodies than could be expected in the colostrum of an industrial cow.

Warne (1990) described a similar product available for piglets and emphasized the economic advantages of the product considering the number of immunological challenges encountered by piglets. The first few hours of birth are uncertain due to sibling competition and movement of the sow just prior to parturition into new environmental conditions which may present pathogens for which she has no specific antibodies.

This particular study investigated the benefits of using a manufactured ewe colostrum supplement (Imulam) to feed neonatal lambs. The dried colostrum supplement originated from an authentic colostrum pool of continental dairy sheep. It was sterile in terms of bacteria and viruses and had a stated composition of oil $< 1\%$, protein 56%, ash 5.5% and IgG 45% on a dry matter basis.

This study was also concerned with assessing the immunological status of beef suckler calves from serum immunoglobulin concentrations. The calf serum immunoglobulin concentrations were examined in order to indicate any variation which occurred due to the dietary protein intake of the beef suckler cows during pregnancy.

EXPERIMENT 6. ASSESSMENT OF SERUM IMMUNOGLOBULIN CONCENTRATIONS OF BEEF SUCKLER CALVES.

INTRODUCTION

This experiment was performed using beef suckler cows and their newborn calves. Colostrum samples were taken from the cows as soon as possible, and always within the first six hours after parturition. Calves were given free access to suckler adequate colostrum within the first six hours of birth, and blood samples were taken 24 hours later.

The object of this experiment was to determine the protein concentration of beef cow colostrum and the serum immunoglobulin concentrations of beef suckler calves. Immunological assessment of the serum was performed in order to detect any differences which might occur as a result of the variations in dietary protein intake during pregnancy.

MATERIALS AND METHODS

Animals and Management

Twenty five Hereford X British Friesian cows, mated to a Charolais bull, were fed in three groups during pregnancy. Just prior to parturition the cows were individually housed in loose boxes, well bedded with straw. At birth each cow was examined, the navels treated and birthweights recorded. The cows were checked for milk let-down and any udder problems. The calves were encouraged to suckle as soon as possible after birth to ensure an adequate colostrum intake. The cow and calf were housed in the loose box for 48 hours after which, providing there were no problems. They were returned to the appropriate group of cows.

Feeds and feeding

Three groups of cows, mean liveweight 486kg, were given different dietary concentrate rations in addition to receiving 6kg FM hay/head/day. The hay supplied 44 MJ ME and 151g DCP as part of the daily nutrient requirements. Table 6.1 describes the total dry matter (DM), metabolisable energy (ME) and digestible crude protein of each diet. One of the diets supplied substantially more and another substantially less protein than the normal recommended intake.

Table 6.1 The dietary nutrients supplied to the cows during pregnancy, when either SUPERGRAINS (SG) DCFMIX or molassed sugar beet pulp (MSBP) forms part of the diet.

Nutrient	Diets		Requirements pregnancy intake
	SG	DCFMIX	MSBP	(ADAS 1976)
DM (kg)	7.1	7.1	6.6	___
ME (MJ)	76.1	65.2	65.5	67
DCP (g)	705	407	288	430

Further details concerning the housing and feeds of cows receiving SG or DCFMIX has been described in Experiment 4. The remaining group of cows were given 2kg MSBP plus supplementary minerals and vitamins but with no additional protein.

Blood samples

10ml blood samples were taken from the jugular vein of each calf, 24 hours after birth, into non-heparinised vacutainers. Logan, Penhale and Jones (1973) and Logan, McBeath and Lowman (1974) reported the optimal peak of serum immunoglobulins in calves to occur 24 hours after the first suck. The vacutainers were left overnight at room temperature to allow the formation of blood clots. The serum was removed using a pasteur pipette and stored at -20^{o}C until required.

The serum samples were analysed to determine the serum immunoglobulin concentrations. The zinc sulphate turbidity test (McEwan, Fisher, Selman and Penhale, 1970) was employed and defined the immunoglobulin content in terms of ZST units. Further examination of the specific immunoglobulins was performed using radial immunodiffusion techniques (Fahey and McKelvey, 1965). Diagnostic kits (Serotec Ltd.) were used to determine IgA, IgM, and IgG serum levels. Appendix 3 describes the immunological assay techniques.

Colostrum Samples

Within the first six hours post-partum 100ml colostrum samples were taken from each cow. The colostrum samples were stored at -20^{o}C until required. Each colostrum sample was treated with rennet to extract the colostral whey. Analysis of the colostral whey provided the milk protein concentrations.
Appendix 3 describes the procedure for extracting the colostral whey.

RESULTS

In the original groups of cows, during pregnancy 11 cows were given SG, 11 cows were given DCFMIX and 8 cows were given MSBP. Problems encountered during parturition such as uterine prolapse, a stillborn calf and late calving of some cows contributed to the reduced number of calves actually used in each group.

Cows and calves which presented problems during parturition were not used for the purposes of this study. There were no particular husbandry problems observed within the first 48 hours, except for one cow with abnormally large teats. The calf was frequently assisted to suck from the cow until a good feeding pattern was established. No calves displayed symptoms of ill health and all were weighed and blood samples taken without problem.

Restraint of the cows assisted the collection of colostrum samples. The colostrum samples varied between individuals in quantity, consistency and colour. One cow in particular had a very high content of blood in the colostrum, but this did not appear to affect the cow or progress of the calf.

The diets fed to cows during pregnancy can be considered as three different protein diets. SG (high protein, 705g DCP), DCFMIX (medium protein, 407g DCP) and MSBP (low protein, 288g DCP). The results displayed in Table 6.2 describe the cow colostrum and calf serum measurements according to the protein level in the diet during pregnancy.

Table 6.2 Mean values obtained for colostral milk protein, and calf serum ZST and immunoglobulin concentrations.

	Dietary Protein Level		
	HIGH	MEDIUM	LOW
n	9	8	5
Colostral			
Whey Protein (g/kg)	140	125	102
s.e.m.	13.6	7.0	12.7
Calf Serum			
ZST units	40	36	17
s.e.m.	4.1	3.4	3.4
Serum Immunoglobulin			
IgG $mgml^{-1}$	59	60	28
s.e.m.	12.2	11.8	6.2

The mean concentrations (g/kg) of protein in the whey of the colostrum produced by the cows receiving high, medium or low protein intakes were 140, 125 and 102 respectively. Using the statistical t-test to compared the mean values from the high and low protein groups the difference failed to reach significance at $P < 0.05$ (SED = 21.65, t = 1.94) but was significant at $P < 0.1$. There were no significant differences between the mean values for the medium and low protein groups or between the high and medium protein groups.

The mean ZST values for the calf sera when the cows were given high, medium or low protein diets during pregnancy were 40, 37 and 17 respectively. There was a significance difference ($P < 0.01$) between the mean values determined for the high and low protein groups (SED = 6.11, t = 3.76). The difference between the mean values for the medium and low proteins was also very significant ($P < 0.01$) (SED = 5.61, t = 3.47).

The mean concentrations of IgG in calf sera for the high, medium and low protein intake groups of cows were 59, 60 and 28 respectively. The mean serum IgG concentrations for the calves from the group of cows given a low protein diet failed

to show any significant differences (at $P < 0.5$) from the other supplemented groups. There was a significant difference ($P < 0.1$) between the mean values of the high and low protein diets (SED = 16.64, t = 1.86). A significant difference at $P < 0.1$ was also shown between the mean values for the medium and low protein diets (SED = 15.78, t = 2.03).

The individual immunoglobulins determined using radial immunodiffusion techniques were difficult to determine accurately. The degree of antigen-antibody precipitation extended beyond the limits of the calibration curve. Definitive values could only be determined for IgG. Table 6.3 describes the range of concentrations determined for IgM and IgA. From these results there was a good indication that calves born to cows given lower dietary protein levels during pregnancy had lower serum IgM and IgA concentrations. Only one calf, from the low protein group showed an IgM concentration greater than $5mgml^{-1}$. Almost half of the calves in the high and medium protein groups showed serum IgM concentrations over $5mgml^{-1}$. Application of the chi-squared test to the data, shown in Table 6.3, indicated a significant relationship between dietary protein intake and serum IgM ($P < 0.01$) and IgA ($P < 0.05$) concentrations.

All the calves in the high and medium protein groups showed serum IgA concentrations greater than $0.5mgml^{-1}$. Nearly half of all the calves in the low protein group had serum IgA concentrations less than $0.5mgml^{-1}$.

Table 6.3 The number of calf serum immunoglobulin concentrations, IgM and IgA, which were within given ranges ($mgml^{-1}$) of concentration.

IgM $mgml^{-1}$	Total n	9	8	5
< 1		0	0	3
1 - 2		2	0	1
2 - 5		3	2	0
> 5		4	6	1
IgA	Total n	9	8	5
< 0.5		0	0	2
> 0.5		9	8	3

DISCUSSION

Kruse (1970) described the importance of immunoglobulins for the health of neonatal calves born virtually agammaglobulinaemic. To achieve adequate immunoglobulins from maternal colostrum, the colostrum must contain sufficiently high concentrations of immunoglobulins. Also, the calf must have the ability to efficiently absorb ingested colostrum and there should be no extravenous obstruction of these processes which would reduce colostral Ig transfer. Kruse showed from experimental work that large individual variation exists in the yield of colostrum. Further evidence for this variation has been attributed to parity (Steinbach and Meyer, 1965), seasonality (Gay, Fisher and McEwan, 1965) and the interval between calving and first milking. A detailed account of the factors affecting the yield and contents of milk constituents of commercial importance has been published by the International Dairy Federation IDF (1980). During lactation the amount of milk protein secreted can be influenced by the dietary intake and consequently it is feasible to assume that milk composition in late pregnancy could be affected by the dietary regime.

The significant differences ($P < 0.1$) between the whey protein of protein supplemented groups of cows and the non-supplemented group suggest that there may be a relationship to the urea concentration in the blood of the cows at 24 hours after calving. The mean blood urea concentrations of the cows given high and medium protein respectively were 11.9 ($\pm$ 3.9) and 6.3 ($\pm$ 2.1) mmol l^{-1}. The difference between the two groups was very significant ($P < 0.1$) (SED = 1.48, t = 3.79).

Unfortunately no blood samples were obtained from the cows receiving the low protein diet. It could however be reasonably assumed that the blood urea concentration is likely to be lower than for the supplemented groups. If this assumption is valid, a very low blood urea concentration might be indicative of a very low colostral whey protein which, in turn, may be reflected in a lower immune globulin concentration in the calf serum.

The significant differences determined between the mean ZST values of protein supplemented and non-supplemented diets in this study have also been described

in a similar study. Fishwick and Clifford (1975) described the effect of two different protein intakes (provided as supplementary urea) containing 200 and 372g DCP, on the calf serum immunoglobulin concentrations which were 26.1 $\pm$ 3.79 and 27.3 $\pm$ 3.25 respectively born to beef cross heifers. Although the results were not shown to be significant similar results were obtained as in the present study for comparable DCP intakes.

A study conducted by Logan (1974) with beef suckler calves emphasized the importance of determining individual serum immunoglobulin levels. Determination of the total immunoglobulin content may not identify calves at risk from colibacillosis. The determination of individual serum immunoglobulins is of particular importance when considering the relative absorption period of each class of immunoglobulin.

Langholz et al. (1987) reported the incidence of disease in calves with inadequate quantities of circulating immunoglobulins. This study also described the relationship between colostral immunoglobulin content and serum immunoglobulin concentrations.

These results were obtained with cows in good body condition and which calved in ideal circumstances. The calves were closely observed and encouraged to suckle from the cows within the first few hours of birth. Logan, McBeath and Lowman (1974) described a reduction in serum immunoglobulin concentration when the colostrum was bucket-fed to calves, compared to calves which suckled naturally.

The general conclusion from the present work is that a protein intake below that recommended in late pregnancy depresses the potential benefits to be derived from colostrum intake. In an alternative situation when the conditions are less than satisfactory the effect on calf health may be expected to be more dramatic.

EXPERIMENT 7 ASSESSMENT OF SERUM IG CONCENTRATIONS IN NEONATAL LAMBS GIVEN COLOSTRUM SUPPLEMENTS.

INTRODUCTION

This experiment involved the study of neonatal lambs from multiparous births from housed ewes. The lambs were allocated to treatments in which either an artificial ewe colostrum supplement, or cow colostrum or ewe milk substitute were fed. The lambs were kept in warm, dry conditions for 24 hours after which blood samples were taken. The blood samples were used to assess the serum immunoglobulin concentrations of the lambs. The experiment was conducted in order to identify any variation occurring between serum Ig concentrations of treated lambs and of those lambs which were given access to normal maternal suckling.

MATERIALS AND METHODS

Animals and Management

Ewes and lambs fed molassed sugar beet pulp in the diet, as described in Experiment 2, were used in this trial. At parturition each ewe was examined for milk let-down and capability to rear her lambs. Lambs from multiple births, triplets or twins if the ewe was unable to adequately rear two lambs were removed and given a particular treatment. All the lambs removed for treatment were dried immediately after birth and weighed. There was no suckling of the dam. Normal animal husbandry procedures were observed. The navel of each lamb was treated to prevent omphalophlebitis and oral antibiotic dose was administered as a prophylactic measure against watery mouth.

Housing

All the lamb receiving treatments were housed in purpose built sheltered accommodation, with clean straw and a heat lamp away from the main flock. The siblings of the treated lambs remained with the ewes, in the main flock, and were given unrestricted access to normal suckling behaviour.

The colostrum supplement (Imulam) was available as a dried product (fully described on page 104) in convenient packages. Preweighed quantities (9g) were

provided in sealed foil packs and mixed with 100ml of water at 38°C. This constituted one treatment dose.

The ewe milk substitute (Ewbol 315, supplied by BOCM Silcock Ltd.) contained 66.75% dried skimmed milk powder, 25% oil, 24% protein, 5.75% ash, 0.1% fibre and vitamin A (25,000 iu/kg), vitamin D_3 (5,000 iu/kg) and vitamin E (35 iu/kg). The manufacturers instructions were followed to reconstitute the dried milk powder and given to the lambs at 50 ml/kg liveweight.

Treatments

There were four treatments given to separate groups of lambs. These were:

Group 1 First feed of reconstituted proprietary ewe colostrum supplement (Imulam) plus additional feeds of cow colostrum up to 24 hours.

Group 2 All feeds up to 24 hours of cow colostrum alone.

Group 3 First feed of reconstituted proprietary ewe colostrum supplement (Imulam) plus additional feeds of proprietary ewe milk substitute up to 24 hours.

Group 4 First feed of cow colostrum plus additional feeds of proprietary ewe milk substitute up to 24 hours.

All the lambs treated received four feeds at six hour intervals within the first 24 hours of life. The treatments were all given as 50 ml/kg liveweight. Treatment Groups 1 and 2 formed the major part of the trial. There were only one or two lambs available for Treatments 3 and 4.

Blood Sampling

Blood samples were taken from the jugular vein of all lambs 24 hours after birth. The blood was collected into non-heparinised tubes and the serum separated in order to determine the immunoglobulin status using the zinc sulphate turbidity test (ZST). Ducker and Fraser (1976) demonstrated the optimal peak of serum immunoglobulin concentration to occur at 24 hours (up to 72 hours) after the first suck. Ducker and McEwan (1972) reported a simple, cheap and effective method of assessing circulating immunoglobulin concentrations in neonatal lamb sera. This test was the zinc sulphate turbidity (ZST) test as described by McEwan, Fisher, Selman and Penhale (1970) for neonatal calf sera.

RESULTS

Some lambs were slow to breathe properly after birth but all the lambs were dried thoroughly and appeared healthy when they were given the first feed. There was a wide variation in birthweight from 3.0 kg to 5.5 kg. Most of the treatment lambs were the smallest lamb taken from twins or triplets, but in some instances the largest lamb of triplets was taken in order to leave an evenly matched set of twins with the ewe. Unfortunately, the serum Ig could not be determined for one of the treated lambs due to the inability to obtain a blood sample, despite repeated attempts.

There were no deaths and all the lambs were in good health after 24 hours and were subsequently reared by hand using ewe milk substitute.

Table 7.1 Mean ZST values (units) determined for serum samples taken from lambs 24 hours after birth and compared to serum Ig concentrations determined for sibling lambs allowed normal maternal suckling.

Treatment Group	Serum immunoglobulin content ZST units					
	Treatment Lambs			Sibling Lambs		
	n	$\bar{x}$	sem	n	$\bar{x}$	sem
1 Imulam/ cow colostrum	5	3.7	1.06	9	28.0	3.11***
2 Cow colostrum only	4	5.4	0.57	7	38.4	3.60***
3 Imulam/ewe milk substitute	4	2.6	1.34	1	30.6	0.00***
4 ewe milk substitute only	2	3.6	1.0	2	26.3	13.65

The mean values determined for the immunoglobulin content of lamb sera are shown in Table 7.1 as ZST units. The bottle fed treatment lambs showed a much lower serum Ig content, 2.6 - 5.4 ZST units, than those lambs receiving normal ewes milk from suckling, 26.3 - 38.4 ZST units. These differences were highly significant.

The reconstitution of the dried colostral supplement (Imulam) was not as suitable as described in the information provided by the supplier. The actual mixing procedure, 9g of supplement with 100ml of water, according to the manufacturers instructions, produced an aqueous solution with the majority of the supplement present in suspension.

DISCUSSION

No lambs died during the trial but this may not be attributable to the acquisition of immunity. It might be explained by the absence of challenge from potential infectious agents within the flock. The lambs were housed in a very clean well-bedded environment with limited exposure to infectious agents.

The results described in Table 7.1 for serum immunoglobulin levels show that natural maternal suckling of the sibling lambs which remained in the main flock provided the lambs with a much higher concentration of serum immunoglobulin. There was insufficient data available for treatment Groups 3 and 4 for the assessment of sibling immunoglobulin levels. From the data obtained, the proprietary ewe colostrum supplement (Imulam) did not appear to provide any beneficial effects for improving the concentration of circulating immunoglobulins in neonatal lambs. These observations are of a similar nature to those reported by Haines, Chelack and Naylor (1990) for a range of commercially available colostrum supplements fed to calves. The authors suggested that the potential benefits of such colostrum supplements were more appropriate for hypogammaglobulinaemic calves than for colostrum-deprived calves.

Abubakar (1989) reported no significant difference between lamb liveweight or zinc sulphate turbidity measurement when the ewes were fed either normal sugar beet pulp or limed sugar beet pulp, under similar conditions of husbandry and housing. Any differences occurring must therefore be due to the initial feed given to the lambs.

The problems encountered with the colostral supplement as an aqueous suspension may affect the digestibility and availability of the immunoglobulins. A consistent homogeneous solution would be more appropriate for the newly formed digestive tract of the lambs. Also, this product was recommended as a supplement to the first feed. The importance of gaining immunoglobulins via the colostrum within the first six hours of life has been reported by Ducker and Fraser (1976). The success of Imulam in providing neonatal lambs with adequate quantities of circulating immunoglobulins may be improved by more than one feed within the first 24 hours. This suggestion does however affect the cost of such a prophylactic treatment.

GENERAL SUMMARY AND CONCLUSIONS.

This study examined the contribution of by-product feeds to meet the nutritional requirements of sheep and cattle. Oldham (1988) reviewed the nutrient allowances for ruminants and discussed the requirement, response and dietary allowances of individual nutrients. Earlier studies have concentrated on one aspect of ruminant nutrition, namely (ADAS, 1983) mineral, trace element and vitamin allowances and energy and protein allowances. These publications were in response to the ARC (1980) Technical Review for Nutrient Allowances.

In addition to recognising the nutrient interactions and nutrient availability, nutrient allowances are based upon a particular production system for a given age or liveweight of an animal. Throughout the present study attempts were made at every opportunity to compare the nutrient contribution of the by-product feeds to the published predicted requirements and allowances. The appropriate factors, such as breed, liveweight, age etc. were taken into consideration. Oldham (1988) considered that nutritional evaluation should be concerned with the predicted response and consider in more detail the partition of nutrients and animal characteristics. This study has concentrated on the production benefits of feeding by-products and the traditional proximate analysis, digestibility and degradability of the feed. The results from this study are encouraging and identify the potential benefits and also problems associated with using these novel by-products as ruminant feeds.

To provide the type of information suggested by Oldham (1988) for predicting the response of feeding these particular by-products further studies are required into the influences on biochemical and microbial function.

The definition of the value of a ruminant feed is concerned with the quantity of available protein, contribution of the microbial population and the metabolisable energy content of the feed. Webster, Dewhurst and Waters (1988) described a simulated model, MENTOR, as a characterisation of feedstuffs for ruminants based upon the true metabolisable energy and metabolisable protein. The validity of the model is dependant on the interactions between fermentation, degradation and microbial protein synthesis in the rumen. Also, the truly absorbed energy and

nitrogen fractions require accurate description when considering the physiological state of the animal and feed chemistry analysis.

To improve the validity of simulated models and prediction equations data should be obtained and applied to the models. This will assist in identifying the areas of weakest knowledge. Prediction equations are an important aspect of nutritional evaluation due to the expense and time consuming methods of direct determination of metabolisable energy.

The prediction of metabolisable energy content of compound feeds has been investigated by Thomas et al. (1988). Similar mean metabolisable energy values were obtained for sheep (12.91 MJ) and cattle (12.58 MJ). Fat and fibre were the two nutrients which caused the greatest influence on metabolisable energy. The E3 equation for compounded concentrate feeds was shown to be the most reliable (RMSE = 0.24) where ME = 0.250 oil + 0.140 NCD (NCD is the cellulase digestible organic matter remaining after neutral detergent extraction). The authors suggest limitations to the use of this equation, especially when considering cows fed diets containing high levels of sugar beet pulp and citrus pulp.

The primary feed evaluation performed in this study was the determination of digestibility. Wether sheep housed in metabolism crates were maintained in adequate environmental conditions. The sheep were not isolated and were given full visibility of other sheep and experimental staff. Hecker (1983) describes the specific attributes of using sheep as experimental animals. The British Federation of Animal Welfare (BFAW) Code of Practise for Experimental Animals was followed. The sheep became quickly accustomed to the environment and any sheep reluctant to consume the allocated feed or displaying minor health problems were removed from the experiment. During the whole study no serious health or abnormal behaviour problems were encountered. The consistent, reproducible digestibility data obtained showed minimal variation and consequently the use of sheep in metabolism crates was both appropriate and satisfactory. There are particular considerations which must be given to any digestibility trial. These are the effect of feeding at maintenance levels, associative effects of the feed and the repeatability and application of results.

The beef cow digestibility trial, using a chromic oxide marker may have been affected by the initial selection of cows which preferentially chose wheat distillers SUPERGRAINS as the concentrate feed source. It is difficult to formulate chromic oxide in a feed with an even distribution. This study showed a consistent chromium content even at a low concentration in a barley cube form. The percentage recovery of chromic oxide should have been determined for each trial in order to improve the accuracy of the digestibility data.

The production trials with lactating ewes, lactating dairy cows and pregnant and lactating beef cows were conducted as near to normal farming practise as possible. The animals were subject to the legal requirements of the Animals (Scientific Procedure) Act (1986). The extent of variation was greater in these studies due to individual variation according to age, parity, liveweight etc. in comparison to the wether sheep used in digestibility trials which were of a similar breed, age and weight.

Greater accuracy may be achieved for the degradability studies by feeding a diet consisting mainly of the trial feed. Ruminal adjustion to different feed sources by the microbial population improves the efficiency of utilisation and ultimately affects the rumen environment with respect to volatile fatty acid content.

Overall, biological feed evaluation is superior to in vitro methods at the present time, but improvements in determinative methods may eventually produce standard, repeatable techniques. This would reduce the need for experimental animals in determinative tests which have been employed for over 130 years.

The livestock trials conducted in this study have shown that two novel sugar beet by-products, limed molassed sugar beet pulp (LMSBP) and an extract (EXT) are suitable as ruminant feeds. Production trials with LMSBP have shown this by-product to be of equal value when fed to lactating ewes as a traditional molassed sugar beet pulp by-product. The importance of the LMSBP as a novel by-product are the elevated calcium and phosphorus levels, in comparison to a normal molassed sugar beet pulp. Increased calcium and phosphorus levels are important in feeds for lactating dairy cows (2.84g Ca and 1.8g P required/kg milk produced) to prevent the health risks from milk fever.

Limed molassed sugar beet pulp contains (/kg DM) 60g digestible crude protein and 11.1 MJ ME which compares favourably with a standard molassed beet pulp (61g DCP and 11.5 MJ ME/kg DM). Recent detailed assessments of the value of sugar beet pulp have been reported by Crawshaw (1990). Using sheep digestibility studies, similar to the experiments conducted in the present study, nutritive values were determined for dried molassed sugar beet feed.

The digestibility (%) values determined in the present study for the LMSBP by-product and a normal MSBP by-product were below the range reported by Crawshaw (1990) as 87-92 organic matter, 67-75 crude protein and 87-98 crude fibre. The present study obtained similar values for dry matter and crude protein content but gave higher values for crude fibre, ether extract, ash and nitrogen free extract. The article published by Crawshaw (1990) does not indicate the gross energy content of sugar beet feed or the method employed for determination of the metabolisable energy. The gross energy values determined for MSBP and LMSBP in the present study were 16.5 and 16.4 MJ respectively. In the present study care was taken to select appropriate prediction equations rather than applying generalised equations.

The assessment of an extruded extracted sugar beet by-product has provided useful information concerning the nutritive value of this by-product. It is a well digested by-product with D-value of 736g/kg DM, slightly lower than that for MSBP (769g/kg DM). This by-product is particularly resistant to ruminal protein degradation and any future work may concentrate on examining this by-product as a component of a mixed diet for ruminants in a more palatable form with increased amounts of rumen degradable protein.

The mixed by-product containing molassed sugar beet pulp and dried brewers grains was shown in this study to be a potentially useful feed for ruminants. This by-product has a much higher phosphorus (2.32g/kg DM) content than any of the other by-products examined, but a lower calcium content of only 6.39g/kg DM. The reduced calcium content would affect the suitability of this by-product as a sole feed source for lactating cows and ewes. The brewers grains component of the feed increased the protein content of a standard molassed sugar beet pulp and provided more rumen degradable protein.

This novel by-product was in a convenient dried form and was shown to be a highly palatable feed for ruminants. The high energy and protein contents should allow an increased intake of cheaper fibrous feed which promotes rumen activity and improves feed efficiency.

The evaluation of a novel by-product from whisky distillation formed a major part of the present study. Wheat distillers SUPERGRAINS is the residual by-product from a wheat fermentation and distillation process in which the total cereal fraction remains until the final centrifugation stage for separation of the distilled spirit.

The presence of yeast on this by-product probably contributes to the high digestibility of the by-product and the associated production benefits. Gray and Ryan (1990) reported the nutritional benefits of feeding yeast cultures to cattle and sheep. The advantages of feeding yeast cultures to ruminants are an increase in anaerobic rumen bacteria and cellulolytic bacteria together with an increased liveweight gain and feed conversion efficiency for beef cattle. Dairy cattle showed an increase in milk yield plus increases in the butterfat and milk protein content. The authors also noted the biochemical changes of increased ruminal volatile fatty acid concentration and a reduction in methanogenesis. The animals also showed an improved coat and body condition.

The present study examined the use of wheat distillers SUPERGRAINS as a feed source for lactating dairy cows and pregnant and lactating beef cows. The cows thrived on it and the palatability was very good. Unfortunately the complications arising from an inadequate mineral supply, principally calcium and phosphorus, disguised the true benefit of this feed for beef suckler cows. Further evaluation of this by-product should be conducted but the observations reported in the present study should be addressed, principally the deficiency of essential minerals.

This novel by-product feed may be a suitable protein source for growing ruminants. Broster (1973) reported the general effect of additional protein in the diets of sheep and cattle. Increased dietary protein intake, when the energy intake remains constant, has been shown to increase the bone and protein content of the body tissue, whilst decreasing the fat content. Wheat distillers SUPERGRAINS may be

a useful feed commodity for producing animals with the carcass composition currently required by the consumer, high in protein, low in fat.

The high copper content of wheat distillers SUPERGRAINS (144mg/kg DM) has important implications for using this by-product as a major food source for sheep. Sheep are particularly sensitive to excess copper intakes, unlike cattle which can tolerate much higher dietary copper levels. Obviously if cattle were fed wheat distillers SUPERGRAINS over a prolonged period the increased copper intake may be deposited in the liver and eventually elsewhere in muscle tissue. Consequently it would be advisable to monitor the copper levels of tissues and body fluids from cattle fed the by-product over a prolonged period.

Wheat distillers SUPERGRAINS stored as a fresh by-product kept well although some surface mould growth resulted in some material being discarded. When the by-product was ensiled some surface mould growth was also visible, and this contaminated material was discarded. Generally ensilage was a suitable means of storing this by-product but it was noted that increases in environmental temperature contributed to deterioration of the by-product, accompanied by a rancid smell. The high oil content of wheat distillers SUPERGRAINS provides a good substrate for fungal organisms and contributes to the rapid deterioration of the by-product.

Moulds are known to affect the palatability of a feed and subsequently reduce feed intake and feed efficiency and growth (Blaha et al, 1990). The ingestion of mycotoxins, produced by some species of mould, suppresses the cellular immune system and induces secondary diseases due to the impairment of native defense mechanisms and immunogenesis, Jacques (1988). The particular mould species which grows on the feed determines the chemical nature of the toxin produced. Some of the toxins are potent hepatoxins and others cause hormonal imbalance and renal failure. Despite a slightly higher dry matter content of wheat distillers grains (270g/kg DM) in comparison to malt distillers grains (230g/kg DM) the high moisture content encourages mould growth.

Since the observations reported during the trial, regarding mould contamination, attempts have been made to prevent this problem. A formalin solution was introduced to the final product at 5 litres/tonne. Two deliveries of treated wheat distillers SUPERGRAINS were stored fresh over three week periods. The amount of mould contamination was virtually nil and the palatability of the feed by the cows appeared to be unaffected.

Further feeding trials should ideally be performed using this treated by-product in order to ascertain any changes in nutritional value.

One potential disadvantage of feeding wheat distillers SUPERGRAINS over a long period to dairy cows is the incidence of laminitis. A recent review by Greenough (1990) described multiple contributing factors which influence subclinical laminitis syndrome which can exert a major impact on the economic productivity of the herd. Although the precise action of the excess protein levels has not been defined, it has been shown that a reduction in the concentrate component and increased roughage content ($\geq$ 30% dry matter) of the diet reduces the incidence of laminitis in the herd. This is particularly important in heifers and young cows which have not reached maturity before the first calving.

The studies concerning neonatal immunity of ruminants provided some interesting results with respect to the influences of dietary intake during pregnancy of cows on the colostral whey protein and serum immunoglobulin concentrations of neonatal calves.

Further studies might be concerned with examining the transfer of other blood metabolites into the colostrum. In addition to protein transfer of specific maternal antibodies could be investigated. This would then provide information concerning maternal antibody titres, colostrum antibody concentrations and neonatal antibody titres for specific antibodies. This may have important effect on the feeding of cows in pregnancy, and the possibility of vaccinations during pregnancy as an attempt to provide neonatal calves with a complement of circulating antibodies. These are secondary considerations as the most important factor is to ensure adequate intake

of colostrum by calves immediately after birth. The immunological assays require more repetitions using further dilutions of sera to provide results within the limits of the diagnostic test.

The lamb study showed similar results to those reported by Logan, McBeath and Lowman (1974) for cows and calves. Bottle feeding of lambs in comparison to natural suckling of the ewe considerably reduces the ZST values, and presumably the immune status of the lamb, for all the alternative colostrum feeds given. The costs incurred with feeding proprietary colostrum supplements do not appear to be reflected in animal productivity.

This study was concerned with the nutritional effects of feeding by-products from sugar beet processing and wheat fermentation. Processed feeds of either cereal or vegetable origin need to be assessed according to the plant species and variation within that species, the processes applied, the species and class of animal fed and the relative contribution of the processed product to the rest of the diet. Burt (1973) described the four most important physical processing techniques, grinding, pelleting, heat and water treatments.

Chemical techniques can also be applied during the processing procedure, such as calcium hydroxide in the formation of limed molassed sugar beet pulp. Biological processing techniques rely principally on microbial fermentations. The addition of malted barley to wheat initiates yeast enzyme activity in the production of wheat distillers SUPERGRAINS.

Belyea et al. (1989) described the problems inherent with using by-products as animal feeds. The variation in composition, particularly for protein and mineral levels creates difficulties in formulating balanced diets. The book values for by-product feeds may quote figures below the correct nutrient concentration which can severely limit the efficacy of the ration. Alternatively, quoted values may be higher than the actual nutrient content and cause unnecessary expenditure.

Variation in by-product composition may occur over a period of time (due to cropping conditions or processing techniques). Variation in standard book values

also arises from by-products given a designated name. The actual constituents may vary from country to country or even within regions, eg. molasses can occur as a by-product from sugar beet or sugar cane. Further processing can produce a condensed molasses solubles by-product.

Boucque and Fiems, (1988) reviewed the range of agro-industrial by-products. The continual change in agricultural practises necessitates constant evaluation of by-product composition. Human and animal health is paramount and constant vigilance is required concerning potential toxins and anti-nutritional factors.

The by-products examined in this study have been well described, and were of consistent composition throughout the study.

APPENDIX 1

Analytical Chemistry Procedures

The chemical analyses of feed, faeces and blood plasma samples were all officially established procedures, MAFF (1981), and reported as g/kg dry matter.

Dry Matter (DM) Determination by drying known quantities (1-2 kg) of feed or faecal samples at 95^{o}C for 48 hours or until a constant weight was achieved. The dried sample was milled using an 8 inch laboratory hammer mill with a 2mm screen (Christy and Norris, England) and a 200g subsample was obtained for subsequent analysis.

Nitrogen and Crude Protein (CP) The total nitrogen content of the feed or faecal samples was determined using 1g of dried, milled subsample or 3g of faecal slurry. The analysis was performed in duplicate by an automated semi-micro Kjeldahl procedure (Kjell-Foss Automatic 16210). The crude protein content was calculated by multiplying the total nitrogen content by a factor of 6.25. An internal range of standards was run daily to ensure accuracy of the values.

Gross Energy (GE) Dried feed and faecal samples (1g) were prepared using a die operated by an apex hydraulic press. The gross energy content was measured using a Gallenkamp automatic adiabatic bomb calorimeter equipped with a digital data systems calorific value microprocessor. Calibration of the equipment was performed using benzoic acid (supplied by B.D.H. Thermochemical Standards).

Total Ash Dried, weighed, samples (1g) of feed or faeces were heated at 550^{o}C for 6 hours. The amount of residual ash was weighed and the result reported as g/kg DM total ash.

Organic Matter (OM) was determined as the difference between the dry matter and total ash content of feed and faecal samples.

Crude Fibre (CF) Dried samples (1g) of feed or faeces were analysed using an automated procedure (Tectator, Fibretec System).

Modified Acid Detergent Fibre (MADF) was also determined using the Tectator, Fibretec automated system.

Ether Extract (EE) Dried samples (2g) of feed or faeces were heated with 40-60^{o}C petroleum ether in soxhlet extractor units to extract the oil based fraction of the sample.

Nitrogen Free Extract (NFE) was determined as the difference between the organic matter content and the sum of crude protein, ether extract and crude fibre.

Calcium, magnesium, phosphorus, copper and chromium were all determined in feed or faecal samples. The method of Cavell (1955) was employed in the determination of phosphorus content. All the extracted solutions were measured for the specific mineral content by atomic absorption.

Mineral Content of blood plasma

Calcium and Magnesium

1ml of plasma was mixed with 9ml of lanthanum chloride solution (50ml $LaCl_3$ + 4ml $5NHNO_3$, made up to 2 litres with distilled water).
The quantities were measured in mmol l^{-1} using atomic absorption.

Phosphorus

6ml of distilled and 0.3ml of plasma were pipetted into round bottomed centrifuge tube together with 1.2ml of 20% trichloroacetic acid solution. The contents of the tube were mixed and then centrifuged at 3000 RPM for 5 minutes. 5ml of the resultant supernatant were pipetted into a test tube. Added to this were 0.2ml aminonaptholsulphonic acid and 0.8ml (5% ammonium molybdate in 15% sulphuric acid). After standing for 15 minutes the solution was read in a spectrophotometer at 680nm. The results were reported in mmol l^{-1}.

Urea

0.2ml plasma was pipetted into a round bottomed centrifuge tube plus 3.0ml of an isotonic sodium sulphate solution. The mixture was heated at 37°C in a waterbath for 15 minutes, after which 0.2ml urease* suspension was added to each tube. The tubes were stopped with rubber bungs, mixed by inversion and incubated in the waterbath (at 37°C) for 30 minutes.

The tubes were removed from the waterbath and 0.3ml of 10% zinc sulphate solution added and mixed followed by 0.3ml of 0.5N sodium hydroxide solution. After mixing thoroughly the contents were left for 5 minutes prior to centrifugation.

After centrifugation 2ml of the supernatant was mixed with 5ml of deionised water and 1ml of Nesslers reagent, and the solution read at 450nm using a spectrophotometer. The concentration of urea was reported as mmol l^{-1}.

* Preparation of urease suspension. Grind 2 urease tablets in 5ml of 30% methanol solution.

APPENDIX 2

Faecal subsampling and analysis

From a thoroughly mixed bulk collection of faeces, from seven days output, subsamples were removed.

1) 1-2 kg fresh faeces were dried at 95^{o}C for 48 hours and the dry matter determined. The dried faeces was milled using a laboratory mill (Christy and Norris 8-inch mill, 0.8mm mesh screen). A subsample of dried milled faeces was analysed to determine the crude fibre, gross energy, ash content of the faeces using the methods described in Appendix 1.

2) 0.1-0.2 kg fresh faeces were prepared into a slurry to minimise the loss of nitrogen as ammonia during crude protein determination. This method, adapted from the Grassland Research Institute (1961), involved mixing up to 100ml of distilled water with the faeces and 5ml of toluene in a bottom-drive macerator. The toluene is present as a bacteriostatic agent and the formation of a homogeneous slurry enables an accurate crude protein determination to be made. The resultant slurry can be stored conveniently at -20^{o}C until required.

This method of faecal preparation was applied to sheep faeces from total collection and also to the bulk 'grab' samples of cow faeces containing chromic oxide.

APPENDIX 3

Immunological assay techniques

Colostral whey protein determination

From the 100ml colostrum sample obtained from each cow a 20ml subsample was measured into centrifuge tubes. The separation of the whey fraction was achieved by the addition of 1ml of commercial rennet and 0.1ml of 10% calcium chloride solution. The tubes were incubated at 42^{o}C for 2 hours. The samples were centrifuged and 10ml of whey solution was removed with a pasteur pipette.

Each whey sample was analysed by (Kjell-foss Automatic 16210) to determine the milk protein content. The conversion factor of 6.38 was multiplied by the total nitrogen content to determine the concentration of milk protein (g/kg).

Zinc Sulphate Turbidity Test

A simple rapid method for the determination of immunoglobulin concentration in neonatal calf sera has been described by McEwan, Fisher, Selman and Penhale (1970). The method involved adding 0.1ml of serum to 6ml of zinc sulphate solution. After mixing well the tubes were allowed to stand for 60 minutes at 20^{o}C. The precipitate formed was quantified as units of turbidity by measuring the reaction tubes in a photoelectric calorimeter.

Ducker and McEwan (1972) reported the reliability of the zinc sulphate turbidity test, described above, for estimating the immunoglobulin levels in neonatal lamb sera.

Radial Immunodiffusion

Quantitative methods for determining individual immunoglobulin concentrations in serum have been described by Fahey and McKelvey (1965). Prior and Porter (1980) described a simple agar plate technique for evaluating the immunoglobulin concentration in calf serum. This method has been commercially manufactured into a rapid diagnostic test for determining individual immunoglobulin concentrations in bovine sera. The diagnostic kits supplied by Serotec Ltd. were used in the present study to determine the IgG, IgM and IgA levels in neonatal calf serum. The manufacturers instructions for use were followed using serum separated from whole blood. Serum was used in preference to plasma due to the absence of fibrinogen which can affect the antigen-antibody reaction.

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