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THE EVALUATION OF MALT DISTILLERS GRAINS ENSILED WITH MOLASSED SUGAR BEET NUTS AS A FEED FOR RUMINANTS

by

Elizabeth J McKendrick
GI Biol (SAC Auchincruive)

A thesis submitted towards the fulfilment of the requirement
for MASTER OF SCIENCE and comprising a report of studies
undertaken at SAC Crichton Royal Farm, Dumfries in the
Faculty of Science, of the University of Glasgow

September 1991

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ABBREVIATIONS

ARC	Agricultural Research Council
CP	Crude protein
d	days
DAFS	Department of Agriculture and Fisheries for Scotland
DE	Digestible energy
DM	Dry matter
DUP	Digestible undegraded protein
ERDP	Effective rumen degradable protein
FW	Fresh weight
g	gram
k_f	Efficiency of utilisation of ME for gain
kg	kilogram
k_m	Efficiency of utilisation of ME for maintenance
l	litre
LWt	Liveweight
MAFF	Ministry of Agriculture, Fisheries and Food
MDG	Malt distillers grains, commonly known as wet grains or draff (Scotland)
ME	Metabolisable energy
MJ	Megajoules
MLC	Meat and Livestock Commission
MSBN	Molassed sugar beet nuts
SAC	The Scottish Agricultural College
SBP	Sugar beet pulp
SED	Standard error of the difference
SMMB	Scottish Milk Marketing Board
*	Significant at 5% level
**	Significant at 1% level
***	Significant at 0.1% level
t	tonne
VFI	Voluntary feed intake

SUMMARY

The objective of the thesis was the evaluation of malt distillers grains (MDG) ensiled with molassed sugar beet nuts (MSBN) as a feed for ruminant livestock. The following subjects were reviewed:

The voluntary feed intake of ruminants
The use of sugar beet pulp as an absorbent
Trends of agricultural practice

The literature survey gave an account of animal performance results from relevant feeding experiments and considered the agricultural significance and the implications of the use of such a feed in ruminant production systems.

Three experiments were carried out to evaluate MDG ensiled with MSBN as a feed for ruminant livestock.

Experiment 1 assessed the use of MDG/MSBN as a replacer for proprietary concentrate in diets for dairy cows. Cows were fed either concentrate or MDG/MSBN at one of 3 levels – 3, 6 or 9 kgDM, plus grass silage ad–libitum. Cows offered 9 kgDM of MDG/MSBN were unable to consume all the feed, probably due to a bulk restricting factor. Proprietary concentrates were successfully replaced by MDG/MSBN up to the level of 5 kgDM. At this level of replacement milk yield was maintained, but milk fat content was reduced by 3.6 g kg^{-1}.

Experiment 2 evaluated a forage mix consisting of MDG/MSBN, chopped straw and minerals. Dairy cows were fed one of three forages – grass silage, MDG/MSBN/Straw/Minerals (MDG mix) or a 50:50 DM mix of the two already mentioned supplemented with 7 kg of proprietary concentrate. Cows fed MDG mix diets ate 4.5 kgDM more than silage fed cows and total DM intake results were high, especially on treatment MDG (DM intake – 19.3 kg).

There was a mean increase in milk yield of 2.7 kg d^{-1} for the MDG treatments compared to the silage treatment. Milk fat content was similar for cows fed the silage and the silage/MDG diets, however cows fed the MDG mix diet had a reduced milk fat content of 3.1 g kg^{-1}.

The low milk fat content results produced by cows fed MDG diets may have arisen due to the effect of dietary fat. The fat supplied by MDG diets has a high proportion of long chain fatty acids and is highly unsaturated. Malt distillers grains contain high levels of this fat which may lead to a reduction in the mammary synthesis of milk fat.

The final experiment considered the use of MDG/MSBN as the sole dietary constituent in a bull beef finishing programme. The performance of bulls fed this diet was compared to the performance of bulls fed a conventional silage/concentrate diet. Bulls fed MDG/MSBN finished approximately 3 weeks earlier than silage fed bulls. Liveweight gain was 1.56 and 1.35 kg d^{-1} for the MDG and silage diets respectively. Bulls fed the by-product diet consumed more DM than silage fed bulls. As a higher proportion of the energy from the MDG diet was in the form of fat, the energy was utilised with greater efficiency, generating a higher level of performance.

The MDG/MSBN proved to be a flexible feedstuff. Its use was acceptable as a concentrate or forage for dairy cows, and also as the sole diet for bull beef livestock.

In future years, conventional feedstuffs such as proprietary concentrate or grass silage may be replaced or supplemented by evaluated alternatives such as MDG/MSBN.

INTRODUCTION

The many changes in agriculture which have taken place during the past 10–20 years, have led to new feeding regimes and the careful evaluation of a range of concentrate and forage feeds. The imposition of milk quotas in 1984 had the effect of a reduction in the use of proprietary concentrate and an increased interest in alternative concentrate–type feeds in order to reduce feed costs. Environmental issues, brought to the fore by pollution due to silage effluent and also the introduction of new legislation for the standards of silos, have contributed to the farmers' need to consider alternative forages to grass silage. The storage, nutritive value and financial viability of these alternative feedstuffs should be evaluated to allow successful implementation of these feeds in the farmers' chosen enterprise.

This thesis considers malt distillers grains ensiled with molassed sugar beet nuts (MDG/MSBN) as a feed for ruminants. MDG/MSBN was evaluated as a concentrate and forage feed for dairy cows, and also as the sole dietary constituent in a bull beef finishing regime.

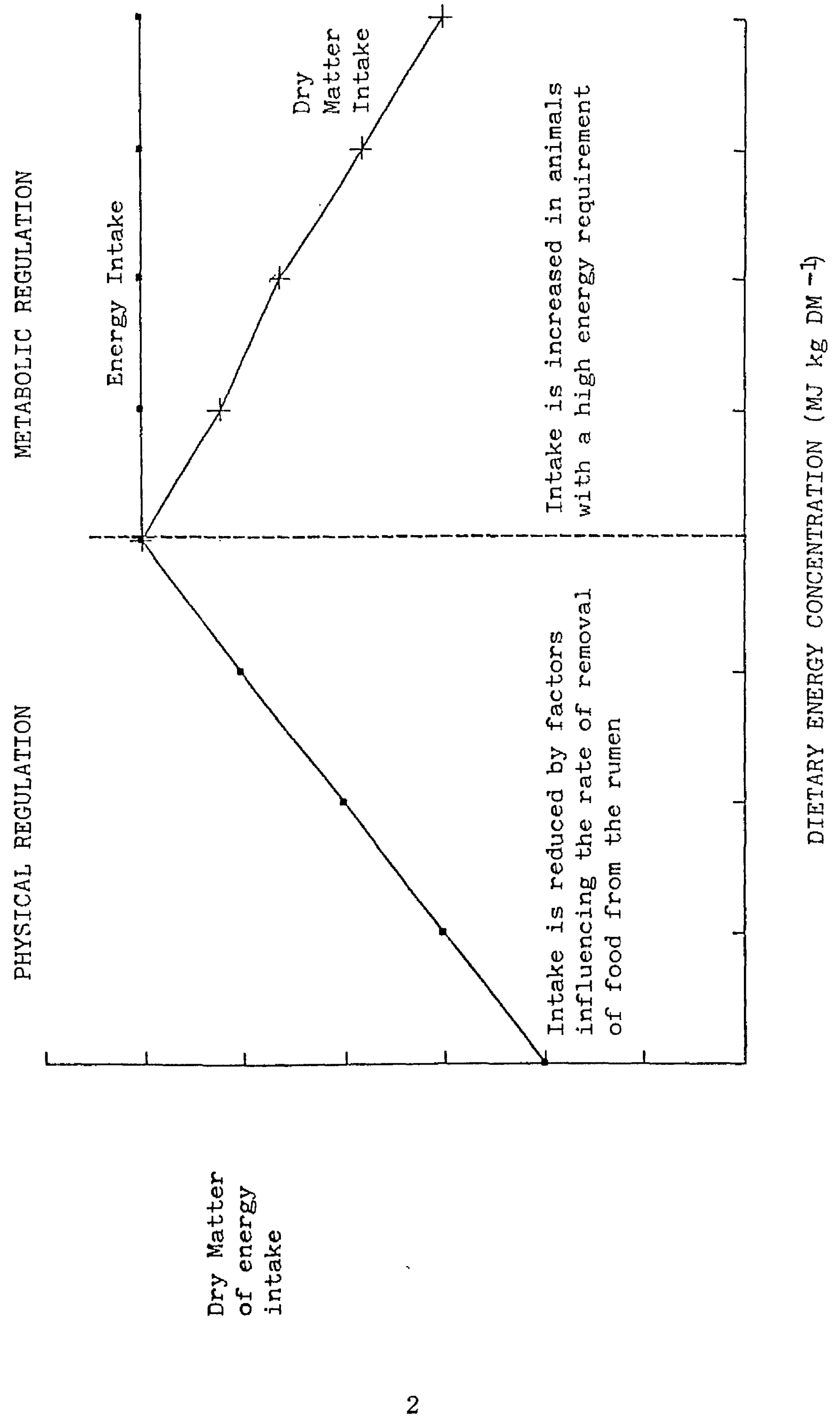
CHAPTER 1 - **REVIEW OF LITERATURE**

Section 1 - The voluntary feed intake of ruminants

The control of voluntary food intake (VFI) is a highly complex phenomena and reasearch has suggested that control is of a multifactorial nature, whereby signals from various receptors involved in negative feedback are interpreted by the central nervous system (CNS) in an additive manner. The hypothalmus integrates information on nutrient requirements and nutrient supply – by means of CNS receptors which are sited in the mouth, nose, digestive tract, liver, brain and elsewhere in the body. These receptors respond to sensory qualities of foods, to the physical effects of food ingestion, to chemical stimuli arising from end products of digestion before and after their absorption and to any appetite–depressing compounds in the food (Forbes, 1986).

When a wide range of feeds suitable for ruminants are readily available, the VFI of the individual feed is dependent on its physical and chemical nature. Generally, the VFI of low–energy forages is regulated by physical fill factors, while the VFI of high–energy concentrates is regulated mainly by the action of chemoreceptors responding to the end–products of rumen fermentation. Thomas and Chamberlain (1982) suggested that a relationship existed between the VFI of the cow and the energy content of the diet. Figure 1.1 summarises this relationship, showing that the regulation of VFI changes from physical to metabolic, as the dietary energy concentration increases. Where intake regulation is classed as physical, energy and DM intake increase with the energy content of the diet.

Figure 1.1. The relationship between voluntary feed intake in the cow and the concentration of energy in the diet (Thomas and Chamberlain, 1982)



Physical characteristics of the diet such as increased chop length and nutritional and physiological factors (eg: low dietary protein content, high dietary starch content and low efficiency of rumination) may reduce VFI by means of reducing the rate of removal of plant fibre constituents from the rumen. During metabolic regulation, energy intake remains constant as dietary energy concentration is increased and DM intake is reduced.

Physical regulation

The bulky nature and low digestible energy content of forages fed to ruminants suggests that the regulation of VFI may be by physical means (see Figure 1.1). Evidence exists to show that the VFI of such diets is limited by the capacity of the reticulorumen and by the rate of disappearance of digesta from this organ (Campling, 1970). This control system was researched by considering 3 areas:

1 The effects on VFI of intra–rumenal additions or removals of food and/or inert materials;
2 The relationship between rumen–fill and voluntary intake;
3 The relationship between the rate of disappearance of digesta and VFI.

Experimental work completed by Campling and Balch (1961) showed that cows could be encouraged to eat for longer periods of time than normal, if swallowed hay was removed from the rumen. The addition of digesta containing recently digested hay to the rumen of cows during a meal, had the effect of an immediate reduction in hay intake. Water filled bladders when placed in the rumen, had the effect of reducing forage DM intake by 0.24kg hay for each 4.23kg of water in the bladders. Johnson and Combs (1991) considered the effect of inert rumen bulk, in the form of polyethylene glycol (PEG) on VFI and rumen kinetics. They concluded that when PEG was added to the rumen, reductions in VFI were smaller than predicted due to compensatory mechanisms such as increased fractional passage–rate and increased organ capacity. The degree of physical 'fill' is monitored by tension and epithelial receptors which respond to increased distension of the gut (Leek, 1986). Research work completed by several researchers (Blaxter, Wainman and Wilson, 1961; Ullyat, Blaxter and McDonald, 1967; and Campling and Balch, 1961) showed that when hay or dried grass was fed to ruminant livestock, eating stopped when the reticulorumen contained similar amounts of dry matter. The quantity of each forage eaten was related to its rate of disappearance from the reticulorumen. A "fill unit" system was proposed by French workers in which the critical fill was found to be a feed-specific characteristic (Jarrige et al, 1986). Fill unit values were assigned on the basis of extensive feeding studies with cattle and sheep. Work completed by Ingalls, Thomas, Tesar and Carpenter (1966), where 4 different forages were fed to sheep, showed the relationship between the DM content of the reticulorumen and the VFI of the 4 forages was not clear cut and suggested that other unspecified factors were involved in the regulation of intake.

Lastly, the rate of disappearance of digesta from the reticulorumen depends upon the chemical composition of the food eaten (Van Soest, 1965; and Hungate, 1966). The cell wall fraction of roughage remains in the reticulorumen for a longer period of time than the rapidly fermented forage fraction and chemical composition is a factor of prime consideration in digestibility.

Physical factors are then of great importance in limiting the regulation of the voluntary intake of roughage diets by means of tension and stretch receptors situated in the reticulorumen, whose action is integrated with other regulatory factors to control VFI.

Forage particle size

Forage particle size is an important factor affecting the regulation of VFI. An experiment examining the VFI of young bulls offered maize silage of 2 different chop lengths, showed an increase of 5.2% in silage DM intake when silage chop length was decreased from 33.3 mm to 7.67 mm (Wilkinson, Penning and Osbourn, 1978). This experiment showed enhanced digestion of both structural and non-structural carbohydrate in the diet with decreased chop length. Deswysen, Vanbelle and Focant (1978) compared the VFI of sheep fed grass silage chopped to either 53 or 18 mm before ensilage. They found sheep fed silage the longer chop length ate less silage and spent less time ruminating than sheep fed silage of a shorter chop length. Jorgensen (1979) considered the VFI of dairy cows fed alfalfa low moisture silage of different chop lengths. He summarised that chopping finer than 6.4 to 9.5 mm had the effect of reducing chewing time and saliva production and no advantage was to be gained in DM intake or milk production.

In conclusion, offering forage of a decreased particle size to ruminants may result in an increased rate of passage and VFI, however increased energy supply and improved performance will only be established if increased forage passage rate is accompanied by an increased rate of breakdown.

Dry matter content of silages

Generally, a positive relationship exists between the voluntary intake of forages and forage DM content (McDonald et al, 1990). This is supported by many workers evaluating the VFI of maize silage (Huber, Graf and Engel, 1965; Owers, 1977; and Phipps, 1990). Demarquilly (1988) suggested that the DM content of maize silage was the 'key factor' that determined energy intake by cattle and hence the performance produced by the basal ration of maize silage. Phipps (1990) reported an increase in intake of 1.5 kg DM by dairy cows when silage DM content increased from 230 to 300 g kg^{-1}. Experimental work carried out in Ireland, where dairy cows and beef cattle were fed grass silage, was in agreement to work previously discussed on maize silage as researchers demonstrated that dry matter content of the silage is an important factor in determining DM intake (Kerr, Brown and Morrison, 1961). Jackson et al (1970) evaluated the relationship between silage DM content and VFI of silage by steers. Four silages were fed with DM contents 190, 273, 323 and 432 g kg^{-1}. In agreement with other researchers work, the cattle fed silage of DM 323 g kg^{-1} ate the most. A possible explanation for this phenomenon is the increased abundance of appetite depressing factors (eg: aldehydes, amines) in low dry matter silages (Neumark, Bondi and Volcani, 1964).

Fermentation end-products

The type of silage fermentation and the resulting fermentation end-products are closely related to the DM content of the silage. The effect of increased voluntary silage intake with increased silage DM content may then be linked to the proportions or concentrations of these fermentation end-products. Since some of the end-products of silage fermentation are also the end products of microbial fermentation in the rumen, the control of intake of other feeds can be derived from a better understanding of the effect of specific chemical components of silage on voluntary intake. Several studies quoted by Thomas and Chamberlain (1982) suggested that relationships exist between intake and factors such as silage pH, the concentration of acids in silage DM (negative correlations) and indices of 'fermentation quality'. These indices include the proportion of lactic acid in the total acids (positive correlation), the proportion of ammonia-N in the total N (negative correlation) and lastly, an index which considers the relative proportions of acetic, butyric and lactic acids – the Flieg index (positive correlation) (Zimmer, 1966). These relationships however are not straightforward and intercorrelations exist between various components.

In conclusion, both physical and chemical factors operate simultaneously in the regulation of VFI. The relative importance of these factors is dependent on the individual feed components of the diet and the physical form of the diet. A further understanding of the effect of fermentation end-products on meal size and frequency will clarify the mechanism by which the chemoreceptors are stimulated, leading to the development of concepts of the interaction of metabolism and nutrient supply in feed intake regulation. Mathematical models to predict intake have been researched by several workers (Forbes, 1983; and Hopkins, 1985). However, before these models can accurately predict intake for a wide range of ruminant diets, the combined relationships between physical and metabolic parameters, upon which the models are based, must be subject to further research in order to improve our understanding of the interactions between mechanisms involved in VFI.

Section 2 – The use of sugar beet pulp as an absorbent

Malt distillers grains are traditionally used as a ruminant feedstuff and are consequently stored on farms. Conventional storage of MDG results in the production of effluent which was quantified by Hyslop, Offer and Barber (1989) as 162 l t^{-1}. No specific regulations exist for the storage of MDG but the Solway Purification Board advise the use of an effluent storage tank and between January and June 1991 two incidents of effluent pollution from MDG were reported to the board.

In order to emphasise the need for careful storage of MDG, this section considers 3 main topics:

1 Potential pollution from effluent;
2 Sugar beet pulp as an absorbent in the storage of grass silage;
3 Sugar beet pulp as an absorbent in the storage of MDG.

Most of the research reported on the use of sugar beet pulp (SBP) as an absorbent has been in relation to the storage of grass silage. It was therefore appropriate to discuss this work and finally to consider a research project reported by Hyslop et al (1989, a) on the use of SBP as an absorbent in the storage of MDG.

1 Potential pollution from effluent

A total of 4141 farm pollution incidents were confirmed by the Water Authorities Association in 1988 (WAA & MAFF, 1989). This is the highest figure ever recorded and represents a 6% increase from the previous year (see Figure 1.2). One of the major causes of water pollution in the reported cases was silage effluent (see Figures 1.3 and 1.4). The Code of Good Agricultural Practice prepared by the Ministry of Agriculture, Fisheries and Food states that:

Figure 1.2

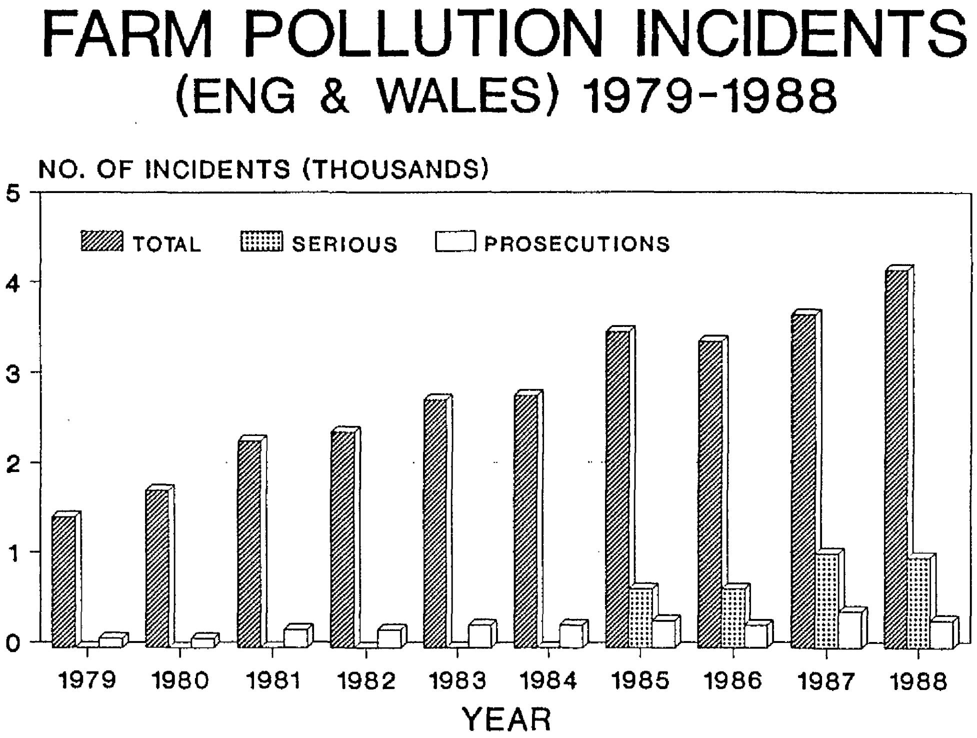

FARM POLLUTION INCIDENTS
(ENG & WALES) 1979-1988
NO. OF INCIDENTS (THOUSANDS)
▨ TOTAL
▩ SERIOUS
☐ PROSECUTIONS
5
4
3
2
1
0
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
YEAR

Figure 1.3

FARM POLLUTION INCIDENTS
(BY CAUSE) 1988

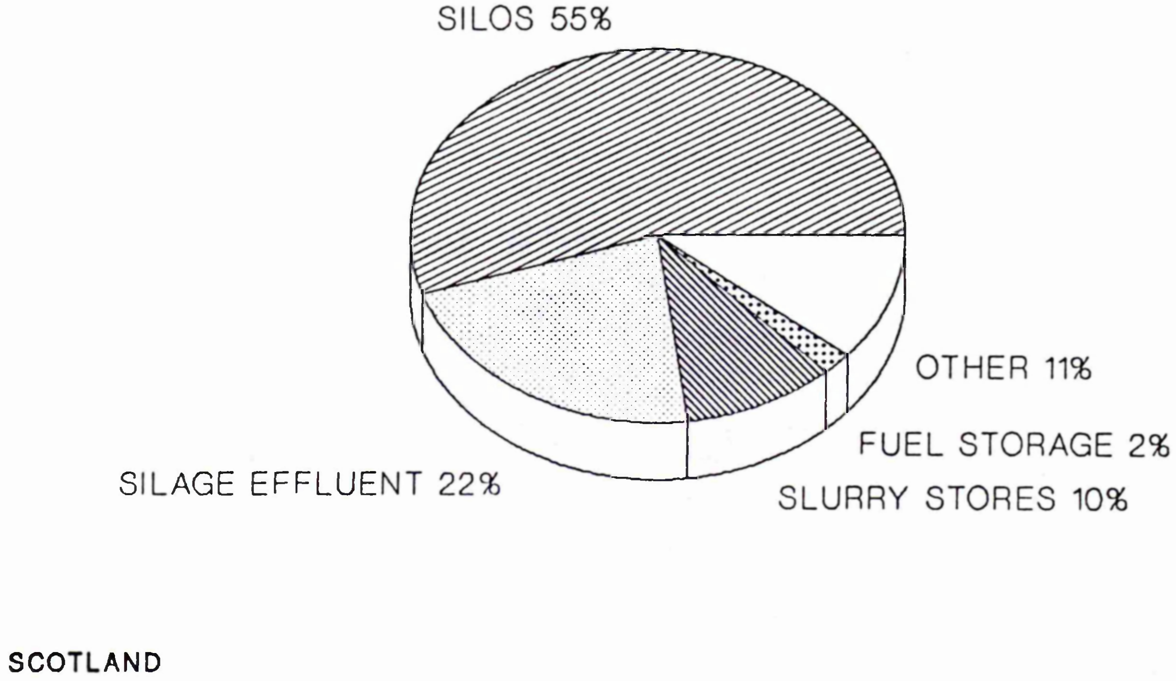
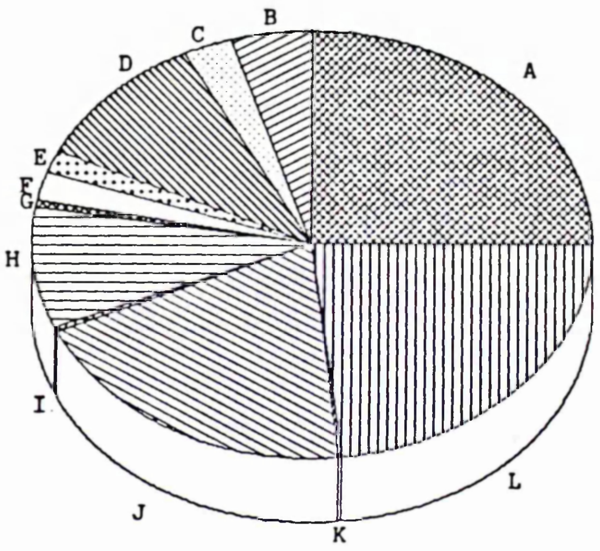


Figure 1.4

FARM POLLUTION INCIDENTS
(BY CAUSE) 1988

Key

A - Slurry stores - 24.9%
B - Run-off-solid stores - 4.9%
C - Treatment system failure - 2.8%
D - Land run-off - 10.5%
E - Sheep dip/ pesticides - 1.7%
F - Oil spillage - 2.2%



Key

G - Mineral fertiliser - 0.5%
H - Other - 9.2%
I - Vegetable Washings - 0.4%
J - Silage effluent - 19.7%
K - Fish farms - 0.2%
L - Yard waters - 23.2%

ENG. & WALES

"Silage production systems should aim to minimise the production of silage effluent consistent with the effective and economical making of good silage".

"Silos should be sited, constructed and maintained to ensure that any effluent is contained and is not allowed to pollute relevant waters".

During the past 10 years the marked increase in the problem of pollution due to silage effluent has arisen due to several contributing factors. As discussed in section 3 of this chapter, the average size of dairy herds has increased greatly and accompanying this expansion was the changeover from hay to silage feeding. This change of ration resulted in a surge in silage production and effluent pollution incidents. The increase in the trend of silage making has led to changes in ensilage technology which have been shown to adversely affect effluent production (Offer and Al-Rwidah, 1989, a). These changes partly reflect the findings of investigations showing increased milk production per animal and per hectare from direct cut crops compared with even moderate levels of wilting (Small and Gordon, 1986). Gordon (1989) suggested that maximum output per hectare could be achieved with a system of direct harvesting, in which the crop was cut and picked up in a single operation. Direct cutting, precision chopping and the use of acid or enzyme additives are now standard practice in silage making in many areas of Britain. Each of these adopted techniques do however increase effluent production per tonne of grass ensiled and therefore provision should be made for storage of an increased volume of effluent. A survey undertaken in 1981 by the Clyde River Purification Board (RPB) in which 100 fodder silos were examined, showed that the vast majority of the silos leaked or had other faults. A follow-up survey by DAFS and the West of Scotland College of Agriculture confirmed the initial findings. Due to increased awareness of agricultural pollution and public concern about the environment, government action has resulted in new regulations concerning this issue. The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) Regulations 1991 introduced new standards which specify the level of performance required from the installation to minimise the risk of water pollution.

Statistics produced by SAC on the DM of silages analysed in the year May 1990–91 showed that the mean DM of pit silages was 220 g kg^{-1} ranging from a mean of 195 g kg^{-1} in Lerwick to 259 g kg^{-1} in St Boswells. Farmers producing silages of such low DM values must clearly look for a solution to the problem of water pollution by effluent discharge in order to avoid prosecution. Several options are available – firstly the appraisal of ensiling techniques may suggest that wilting should be carried out for a longer period of time, however this again introduces a certain degree of reliance on the weather which is not a practical option, especially in Western Britain and the result may be the production of even wetter silages. Secondly, the prevention of leakage by silo reconstruction may guarantee effective effluent storage, however this option is extremely costly. Lastly, the use of absorbents in the ensilage of grass and other forages has been an area under considerable research recently. Absorbents can be used as a successful alternative to conventional additives in the production of a well–fermented silage (Jones, Jones & Moseley, 1990), achieving similar improvements in silage quality, in–silo losses and animal performance, with the additional benefits of reducing effluent and safety problems.

2 Sugar beet pulp as an absorbent in silage

Considerable research work has been completed on the use of sugar beet pulp as an absorbent in grass silage. Work reported by Offer and Al–Rwidah (1989a and 1989b) on the use of absorbent materials to control effluent loss from grass silage, considered using sugar beet pulp as an absorbent both in experimental drum silos and in pit silos.

The initial work showed that when sugar beet pulp was incorporated at 5kg DM (absorbent) per 100kg of grass fresh weight, there was very little effect on silage fermentation compared to the control silage, however effluent volume was reduced by 60% on the SBP treatment. Offer and Al–Rwidah

(1989a) evaluated the composition of the effluent produced and found that the organic matter concentration was greatly increased and so the reduced volume of effluent produced had in fact a BOD_5 of 52.5 g O_2 l^{-1} compared to 20.0g O_2 l^{-1} for the control silage. It is therefore necessary if using SBP as an absorbent, to incorporate sufficient SBP to completely eliminate effluent production and Offer and Al-Rwidah (1989a) experimentally quantified this in the equation:

$$SBP_o = 41.9 - 0.191 \; DM$$

where SBP_o = level of SBP (% FW of grass) needed to prevent effluent production;

DM = grass DM content (g kg^{-1})

NB: Wilting to a minimum of 180g kg^{-1} is required.

The experimental work considering pit silages concluded that SBP, when used as an absorbent in grass silage, had potential in terms of effluent control, enhanced silage digestibility, feed intake and animal performance. Friesian calves fed the silage/SBP had a higher rate of liveweight gain than calves fed silage supplemented by an equivalent level of SBP. Other researchers on the subject of SBP as an absorbent in grass silage have found contrasting results (see Table 1.1). Further research in this area may be justified by the potential suggested by some of the studies discussed for the control of effluent pollution, by the use of SBP as an absorbent, and this approach may lead to clarification of the effect on animal performance.

Table 1.1 Sugar beet pulp as an absorbent in grass silage

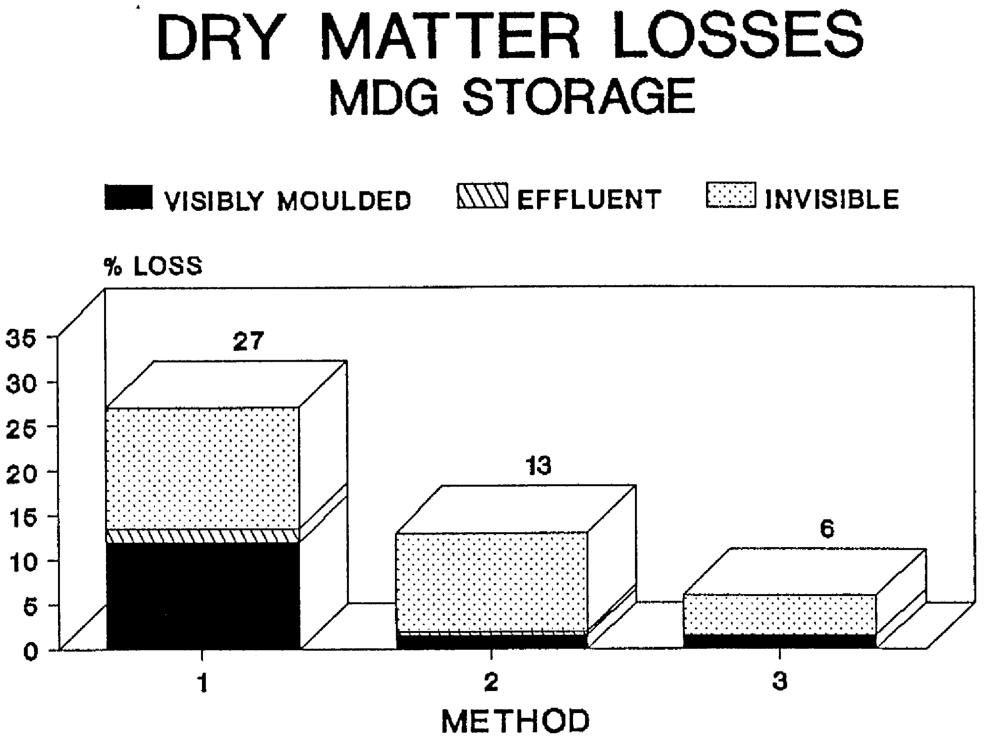
		Effect on *			
Reference	SBP inclusion Rate kg t-1 grass FW	Effluent Volume	Peak Production of Effluent	Fermentation	Animal Performance
Johnston (1991)	20	reduced by 15%	reduced by 32%	No Change	No Change
	40	reduced by 6%	reduced by 29%	No Change	No Change
Davies & Perrot (1991)	50	reduced by 21%	reduced by 48%	Improved	Increased DM Intakes
Ferris & Mayne (1990)	40	reduced by 47%	-	Improved	No Change
	80	reduced by 83%	-	Improved	No Change
	120	reduced by 96%	-	Improved	No Change

* Columns 3-6 in comparison with control treatment (ad-libitum silage plus appropriate level of SBP mixed prior to feeding).

Sugar beet pulp has also been used as an absorbent in alternative forages. Offer (personal communication) completed 2 trials using pit and drum silos to evaluate several absorbents for storage with malt distillers grains (MDG). These experiments evaluated the storage of SBP with MDG – SBP representing 39% of the resulting mixture on a DM basis. Effluent loss was eliminated at this level of SBP incorporation and the MDG/SBP mixture was well preserved, having a pH of 3.82 and a low butyrate content of 0.005 g kg^{-1} FW. Intake and digestibility were also measured using sheep and DM intake was 5.1% of liveweight on the MDG/SBP diet – an increase of 51% in DM intake from the MDG only diet. Further experimental work on the ensilage of SBP with MDG was completed by Hyslop et al (1989a) to evaluate the DM losses associated with conventional storage of MDG and also with MDG/SBP storage. Conventional MDG storage was represented for trial purposes by MDG being tipped into a pit and covered with a top sheet. No compaction or effective sealing was attempted. The MDG/SBP storage method consisted of MDG being ensiled with layers of SBP (158kg t^{-1} MDG FW). The mixture was compacted at layers of 60 cm and sealed effectively using side and top sheets. DM losses were monitored as visibly moulded waste, effluent loss and invisible in–silo losses. The DM losses associated with the two treatments described are shown in Figure 1.5.

Silage fermentation was examined and it was shown that the incorporation of SBP caused a fermentation shift towards increased amounts of lactic and decreased amounts of acetic, butyric and propionic acids. Animal performance was evaluated and the improvement in fermentation led to increased DM intake and liveweight gain on the MDG/SBP treatment, compared to conventionally stored MDG fed on its own or supplemented

Figure 1.5



Method 1 - Conventional storage uncompacted and poorly sheeted

Method 2 - Compacted and sheeted effectively

Method 3 - Compacted and sheeted effectively but with 7 layers of SBP at 158 kg t^{-1} of MDG incorporated during ensilage

Source: Hyslop et al (1989a)

with an appropriate level of SBP at feeding. This particular experiment suggested that storage of MDG with SBP as an absorbent was of significance in practical agriculture and the considerably higher levels of animal performance achieved appeared encouraging and justified more animal performance research.

The present study considers the flexibility of this feed and evaluates animal and financial performance in each production system.

Section 3 - Trends of agricultural practice

In an attempt to evaluate the potential of a feeding system, incorporating by-products such as MDG, it is necessary to consider the changes which have arisen in agricultural practice and the effect of these changes on the implementation of such a system.

Two areas of interest are examined in the review:

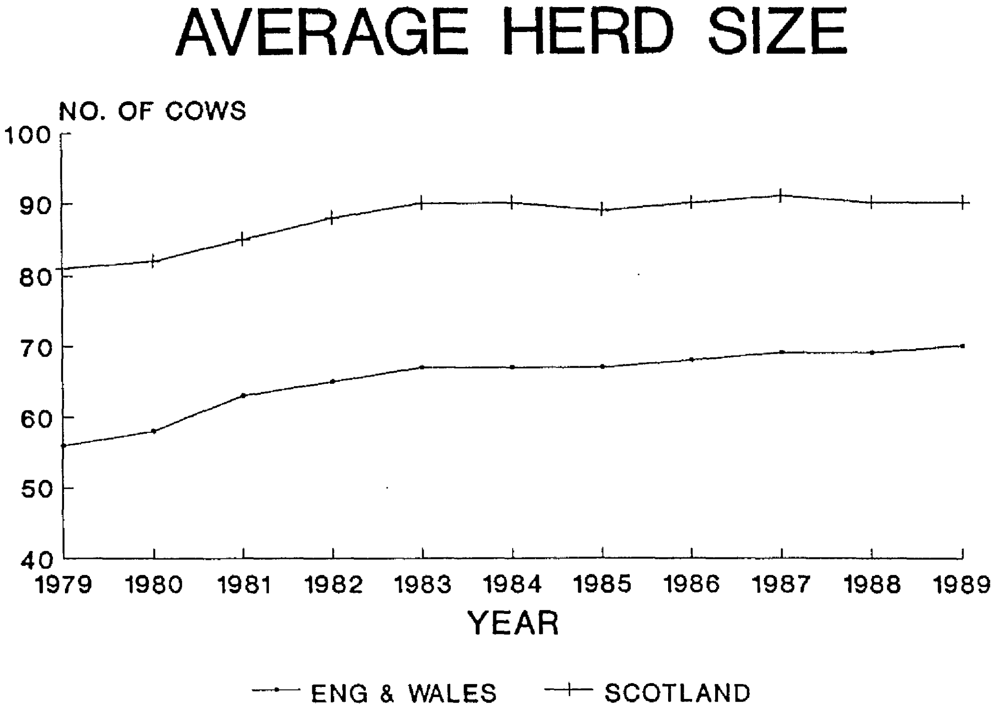
1 General agricultural trends.

2 Housing and feeding trends.

1 General agricultural trends.

Agriculture has undergone many changes in the past 20 years. These changes have enforced the farmer to consider new management strategies, feeding systems and alternative enterprises. The average herd size in England and Wales increased from 56 cows in 1979 to 70 cows in 1989 (see Figure 1.6) and this expansion was accompanied by an increase in farm size of approximately 20 hectares. The implications of those changes and also the reduction in farm labour, was the need for farmers to adopt mechanised feeding and cropping systems which were relatively straightforward to operate and met the needs of a larger dairy herd. The degree of mechanisation on most farms has increased considerably and the use of feed processing equipment in particular has increased notably. Relevant statistical information on the use of feed mixers and wagons is collected infrequently and so is limited. However, between 1973 and 1987 there was a 23% increase in the use of combined milling and mixing units of a fixed or mobile nature (Agricultural Statistics UK) and this suggests that farmers were making use of imported feedstuffs, cereals or distillery by-products due to the convenience, lower price and availability associated with some of these feeds. Due to increased pressure in livestock margins, farmers were keen to try alternative feeds in new feeding systems with the opportunity of using new facilities for handling and mixing feeds. The average milk yield also increased during the past 10 years. The UK average rose from 4760 litres

Figure 1.6



AVERAGE HERD SIZE
NO. OF COWS
100
90
80
70
60
50
40
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
YEAR
ENG & WALES
SCOTLAND

in 1980–81 to 5055 litres in 1982–83. The imposition of the quota system in 1984 however, had the effect of reducing milk production and in 1989–90 the UK average for milk sales per cow was 5010 litres. This reduction in milk production was accompanied by an attempt to maximise utilisation of the silage component of dairy cow rations, and SAC Milk Manager statistics show a reduction in concentrates fed from 0.30kg l^{-1} in 1984 to 0.21kg l^{-1} in 1990. The overall trend of an increase in milk production has been accompanied by changes in production criteria. Both milk production and composition have become extremely carefully monitored throughout the quota year due to the implementation of the quota system and the strive for efficiency in the production of milk at particular times of the year. Table 1.2 shows the trends of costs of production and returns from milk production. The gross output per litre increased to 19.97p in 1989–90 from 12.20p in 1979–80. Inflation accounted for all of this increase in price over the 10–year period. There was no change in amount of purchased feed and homegrown feed as a proportion of total variable costs, which was 85–90% during both years discussed. Gross margin figures of £684 and £330 were noted for the years 1989–90 and 1979–80 respectively. The gross margin increased by a factor of 1.1 over this time period and 90% of this increase was due to inflation.

Agriculture as a whole became less profitable in the 1970's. Due to the reduction in profitability and changes which have taken place in Common Agricultural Policy, during the past 5 years farmers have begun to develop a more businesslike attitude towards their financial dealings.

Table 1.2 Costs of production and returns in dairy farming

	Per Cow			
	1979-80		1989-90	
Gross Output	612	(12.20)	1048	(19.97)
Variable Costs:				
Homegrown Feed	57	(1.14)	77	(1.48)
Purchased Feed	197	(3.93)	234	(4.45)
Miscellaneous	28	(0.55)	53	(1.01)
Total	282	(5.62)	364	(6.94)
Gross Margin	330	(6.58)	684	(13.03)

Figures in parenthesis refer to p l^{-1}.

(The Federation of United Kingdom Milk Marketing Boards, 1982 and 1990).

A survey carried out by Doyle and Tweddle (1990) over the 3–year period 1986–87 to 1988–89, looked at trends in profitability and indebtedness on Scottish farms. 549 farms of different types were considered and they concluded that generally farm incomes improved over the 3 years of the survey. In the last year of the trial the average return on tenants capital was 10% for dairy farms. This level of return was lower than bank interest rates and would be unacceptable in the long term to other industries. Borrowing expressed as a proportion of assets and referred to as gearing, was 25–35% for dairy farms in the first year of the survey. Over the 3 years of the survey there was a reduction in borrowing, reflecting the change in farmer attitudes to financial affairs.

2 Housing and feeding trends

In the past 50 years the traditional cowshed or byre has been slowly replaced with loose housing and large cubicle sheds. Given the larger size of dairy herds and the constraints which they impose upon labour, the design of farm buildings has become directed towards larger buildings such as cubicle houses. These buildings are designed to allow large herds to express the maximum production potential possible in the given conditions. Byres in which individual cows were tethered, necessitated feeding, bedding and dung removal on an individual cow basis (Watson & More, 1962). The manual work involved with byre housing was tedious, however herd size was smaller at this time. Loose housing was the next development from byres and this system allowed simpler management of larger herds. Cows were able to move freely within pens and separate bedding and feeding areas were provided. Cubicles were a simple but revolutionary development in dairy cow housing and were invented by a farmer in the 1960's (The Scottish Farm Buildings Investigation Unit, 1983). Modern cubicle houses facilitate the use of mechanical equipment for the transport and distribution of foodstuffs and bedding. Slurry removal is also a mechanised operation and ensures hygienic conditions for the dairy herd. Wide doors and feed passages in cubicle sheds allow easy access for machinery and contribute to efficient management of larger herds. Loose housing allows the further simplification in feeding of self feed silage systems. The most major change in feeding regimes was the replacement of hay with silage as a means of conserving winter forage (see Tables 1.3 and 1.4). Self feed silage involves the use of a portable barrier, which controls the cows access to the silage clamp and prevents wastage. Self feed silage systems became more popular as herd size increased and the style of housing changed to accommodate these larger herds. Out of parlour concentrate feeding also increased in use alongside these changes. Between 1978 and 1981 there was an increase of 53% in the number of farmers feeding concentrates outwith the parlour. The concentrate was either fed through electrical dispensers or it was mixed in with the forage component of the diet. In 1981, 23% of the farmers who fed out of parlour concentrates, mixed the feeds with forage and this showed a tendency towards complete diet feeding. Complete diet feeding, whereby all dietary constituents are uniformly mixed and fed ad-libitum, allows the farmer to make use of a whole variety of materials in many forms, such as distillery by-products (Owen, 1979). This feeding regime is now widely used throughout the UK and can make use of cheap protein and energy sources. One such source worthy of future investigation are the by-products coming from the Distillery industry. The production and use of distillery by-products will be revised in the following section.

Section 4 – The production and use of distillery by-products

Malt distillers grains are a by-product from the whisky industry which relies on the conversion of cereal starch to alcohol by several biological pathways. Malt distillers select only barley for processing, while grain distillers may use up to 85% alternative cereals such as maize or wheat. The barley undergoes several processes which will be discussed:

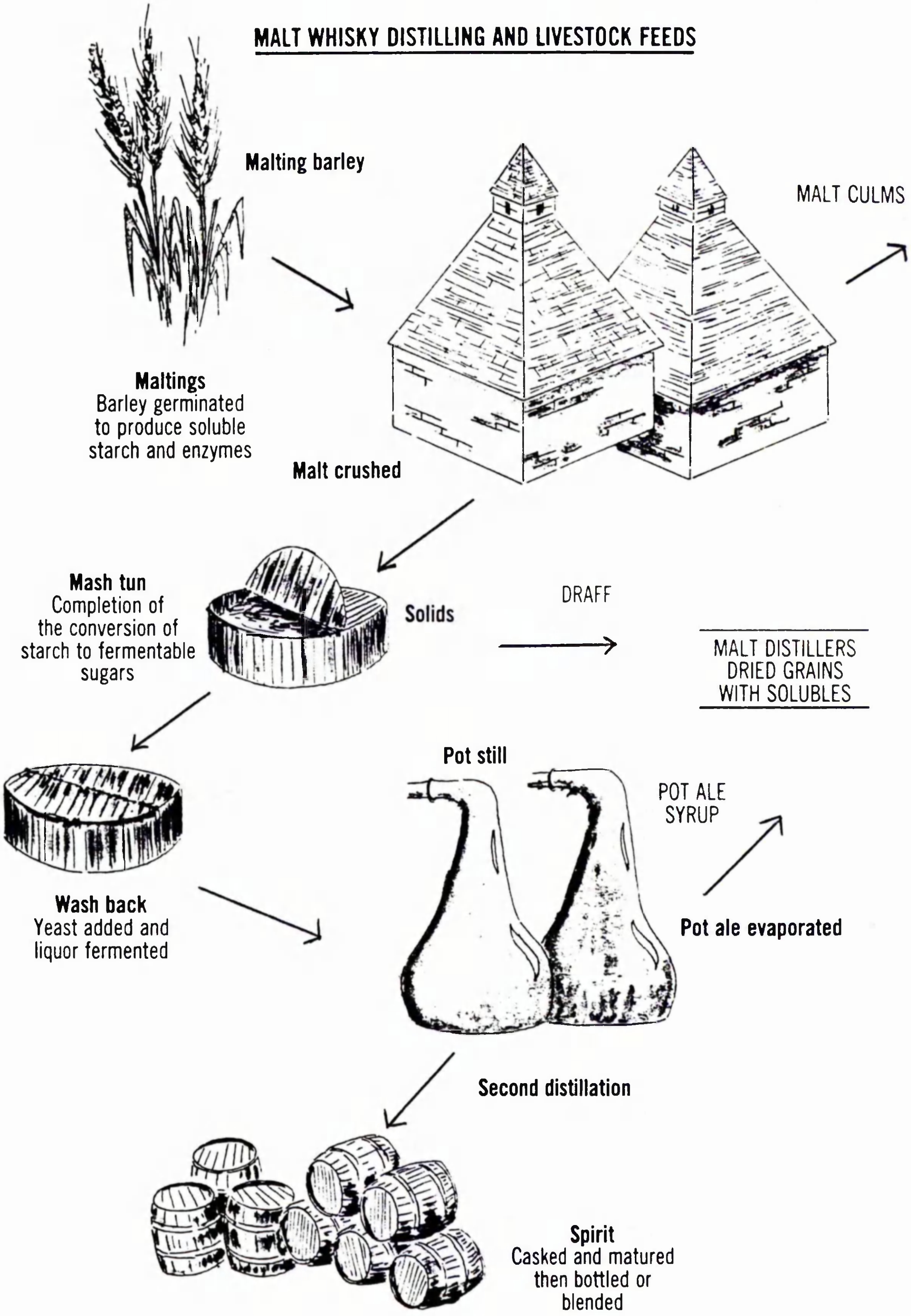
Malting
Mashing
Fermentation
Distillation

These processes are illustrated in Figure 1.7.

Malting

Malting is carried out in Saladin boxes or drum maltings and is a highly mechanised process ensuring the production of malted barley of consistent quality. The process consists initially of the barley being screened to remove foreign material and broken grains, followed by alternative sessions of soaking in water at 15°C for approximately 12 hours and then draining and resting for a few hours. The process ceases when the barley has reached 42% moisture, usually after approximately 2 days. The barley is then germinated at 15°C for a period of 4 days. Temperature and rate of germination is also mechanically controlled and this involves the barley being turned which also avoids tangling of the growing rootlets. It is during the germination phase that the barley embryo begins to secrete an enzyme called diastase, which solubilises starch and converts it to sugar. Drying is the next stage in the process once germination is sufficient. Once dry, the rootlets are removed and the barley is now known as malt.

Figure 1.7


MALT WHISKY DISTILLING AND LIVESTOCK FEEDS
Malting barley
MALT CULMS
Maltings
Barley germinated
to produce soluble
starch and enzymes
Malt crushed
Mash tun
Completion of
the conversion of
starch to fermentable
sugars
Solids
DRAFF
MALT DISTILLERS
DRIED GRAINS
WITH SOLUBLES
Pot still
POT ALE
SYRUP
Wash back
Yeast added and
liquor fermented
Pot ale evaporated
Second distillation
Spirit
Casked and matured
then bottled or
blended

Mashing and the production of malt distillers grains

Before mashing commences, the malt is firstly ground to produce grist which is then mixed with hot water and placed in a "mash tin". Mashing then continues for 5–17 hours and allows the completion of the conversion of starch to sugar. An industrialised water extraction process is then carried out, reducing a sugary liquid called "wort" and the residues are malt distillers grains (MDG), which are sold as a ruminant feedstuff.

Fermentation and distillation

The wort undergoes further processing, fermentation and finally distillation to produce whisky. Live yeast ferment the liquid wort in large fermentation vessels and the soluble sugars are converted to crude alcohol in approximately 48 hours. The resulting liquid known as "wash" is then distilled in two copper pot stills. The residue from the first pot still consists of unfermented material and yeast cell residues and is known as pot ale. The distillate is distilled a second time and the potable spirit is then matured in oak casks for a minimum period of 3 years before being sold as Scotch Whisky.

A number of terms exist for distillery and brewery by-products. To clarify these terms, a glossary is listed below.

<u>Glossary</u>

Brewers grains	a by-product of the brewing industry formed in a similar manner to MDG. Cereals other than barley may be used for brewing and may comprise up to 50% of brewers grains.
Distillers dark grains	formed when a mixture of pot ale and malt distillers grains or grain distillers grains are mixed together and dried.
Draff	a Scottish term for spent grains.

Malt culms	consist of the removed rootlets of the germinated barley at the malting stage of whisky production.
Malt residutal pellets	malt culms and the initial barley screenings mixed and pelleted.
Pot ale syrup	formed when pot ale is evaporated to form a syrup.
Spent grains	a collective term referring to animal feeds formed during the processing of cereal grains in either brewing or distilling.

The use of distillery by-products.

The feeding of distillery by-products to agricultural livestock is by no means a new idea. The sale of wet grains to farmers has been a feature of Scottish agriculture for at least 200 years (Donnachie, 1979). Initially fattening units were attached to distilleries or breweries to make full use of the by-products.

Wet draff became an important source of relatively cheap feed on many dairy and beef farms as the distillery industry expanded. On the contrary, liquid by-products were not utilised but generally discharged directly into rivers or the sea. However, in the 1960's more stringent control of distillery effluent discharge was imposed (Mackel, 1977). Other factors such as the increased production of summer draff due to the rapid expansion of the distilling industry and the rise in world feed prices which prompted distilleries to reassess the nutritional value of liquid by-products, encouraged distillers to maximise the utilisation of all by-products. The result was that distillers partly or totally replaced wet draff production with the production of dried dark grains which was a means of utilising the pot ale syrup and also reduced overall wet draff production by 60%. The production of dried dark grains however, involved the purchase of expensive new drying equipment and also the running cost of these plants. The considerable increase in the price of fuel since 1973 has led to

Table 1.3 Bulk feed systems used on dairy farms in Scotland

	% of Farms	
	1986/87	1980/81
Hay only	2.2	5.1
Hay as part of diet	33.1	52.3
Silage only	-	17.6
Silage as part of diet	83.5	58.0
Silage (self feed) only	11.3	9.4
Silage (self feed) as part of diet	25.6	23.7
Silage (not self feed) only	18.2	8.2
Silage (not self feed) as part of diet	60.0	36.2
Hay and silage only	-	16.5
Haylage only	1.0	1.7
Haylage as part of diet	3.1	4.3
Straw as part of diet	33.8	35.5
Draff as part of diet	28.5	32.2
Kale as part of diet	9.2	16.8
Roots as part of diet	19.5	29.6
Total all farms	100.0	100.0

(SMMB, 1987)

Table 1.4 Feeding trends

	1984		1987	
	Scotland	England & Wales	Scotland	England & Wales
% of Dairy Farmers Feeding:				
Hay	45	62	33	60
Silage	73	74	84	91

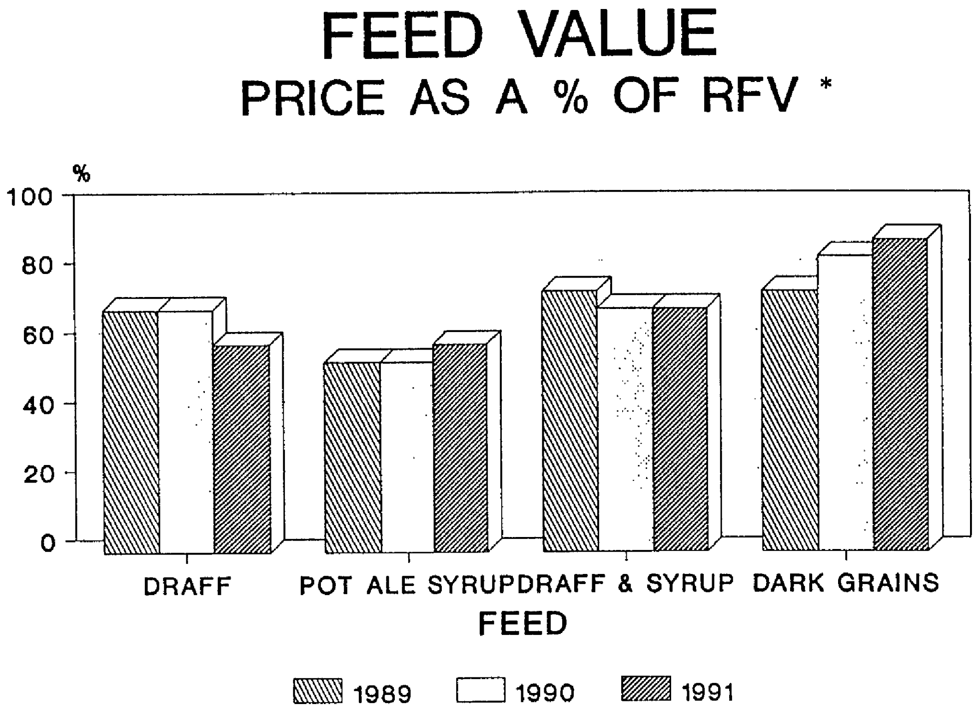
(SMMB, 1984 and 1987)

a reduction in dried dark grain production and a renewed interest in the sale of wet draff to farmers. Figure 1.8 shows the value of different distillery by-products relative to the price of barley and soya over a period of 3 years. Several researchers have evaluated distillery and brewery by-products as concentrate type feeds in dairy cow diets. Table 1.5 summarises this work and will be discussed later in this thesis.

In 1990, 400,000 tonnes of distillery feeds were sold in Scotland – 300,000 tonnes of cattle feed compounds were also sold. Just over half of the 400,000 tonnes of distillery feeds marketed were sold in the form of wet draff (see Figure 1.9). In order to comprehend the trends shown in Figure 1.9, it was necessary to consult the potential buyers of the feed and a report was produced by Lilwall and Smith (1983) which considered the extent of draff use in Scotland in 1979/80 and the attitudes of farmers to this product. Lilwall and Smith (1983) carried out a survey using a postal questionnaire. The questionnaire was mailed to a random sample of 1000 Scottish dairy and beef farmers who each had 20 or more cattle. Scotland was divided into 5 regions and each region was allocated 200 farms, so regional effects could be interpreted. An overall response rate of 69% was achieved which was regarded as satisfactory for a postal questionnaire.

The survey showed that farmers received on average 160 tonnes of draff per year, feeding approximately 0.7 tonnes per head, and the average price in 1979/80 was £19 per tonne, although there was a marked regional difference and the price varied from £6.25 to £28.50 per tonne. Fifty percent of the farmers in the survey had not used draff at any time, but said that they would use draff if it was priced realistically and supplies were reliable on a long term basis. Price however, was not the single determining factor linked with the purchase of draff. If the marketing system under which the draff was sold considered availability and uncertainty, then it was likely that farmer problems would recede. Farmers were under the impression that the problems of feeding, handling and storage could be resolved if the reliability of the product was improved. Thirty percent of draff users taking part in the survey ensiled the draff and of those 12% used an additive which mostly consisted of salt. Again farmers admitted that they would consider ensilage in greater detail if the product

Figure 1.8



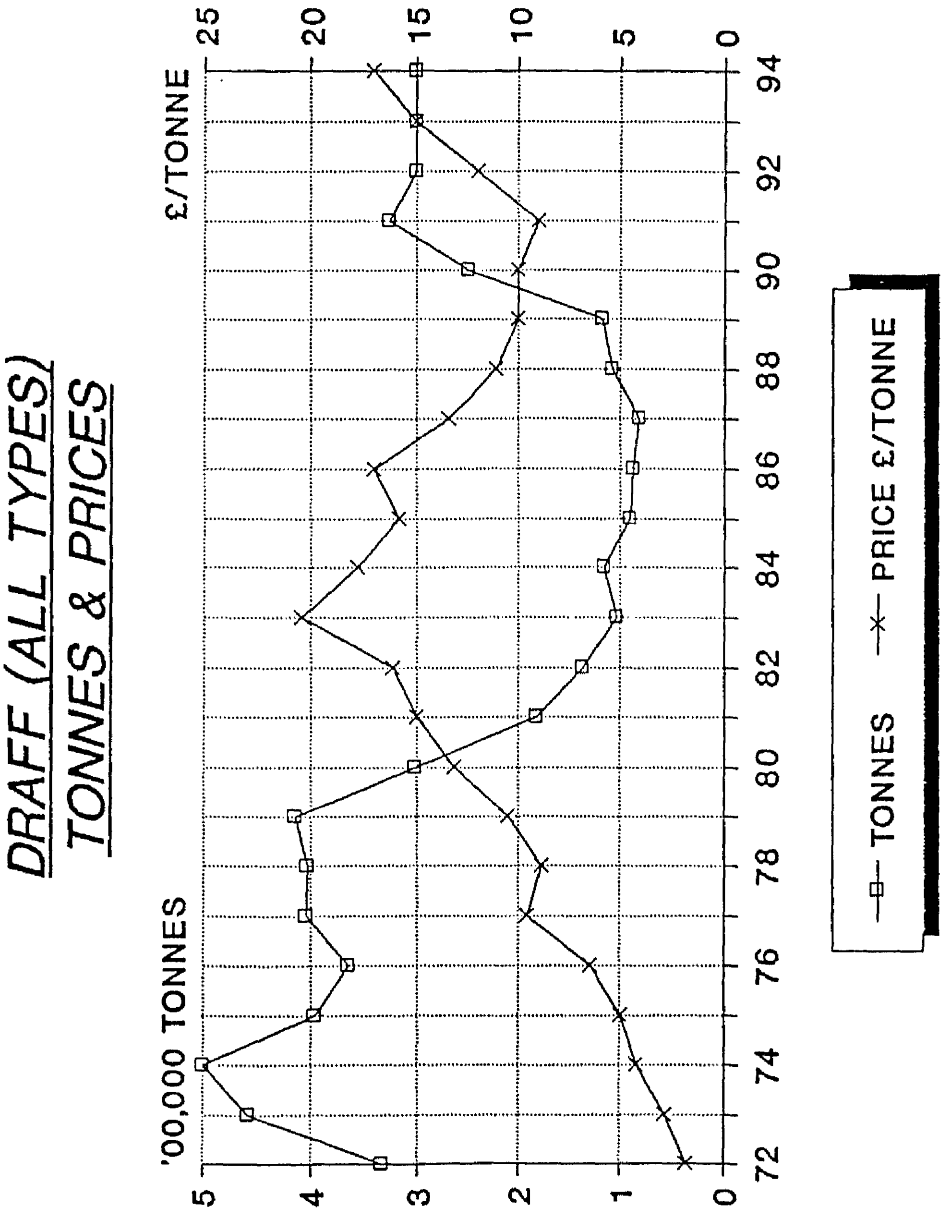
* RFV - relative feed value.

Source: Business Statistics Office.

Table 1.5 The use of distillery and brewery by-products in dairy cow diets.

Reference	Concentrate Replacer Feeding System	% of Total DMI	Effect on Milk Production
Murdock *et al* (1981)	Wet brewers grains Two feeds daily	0.30	No significant differences.
Schingoethe *et al* (1983)	Wet corn distillers grains	0.22	No significant differences.
Castle and Watson (1982)	Malt distillers grains /pot ale syrup. Three feeds daily.	0.26	Increased milk yield. Maintained milk composition.
Hyslop and Roberts (1988)	Malt distillers grains. Two feeds daily.	0.15	Maintained milk yield. Milk fat and protein increased.
Hyslop and Roberts (1989b)	Malt distillers grains. Component of complete diet.	0.30	No significant differences.
Hyslop and Roberts (1990)	Malt distillers grains ensiled with MSBN Component of complete diet	0.47	Maintained milk yield. Milk fat and protein content decreased.

Figure 1.9


DRAFF (ALL TYPES) TONNES & PRICES

SOURCE BUSINESS STATISTICS OFFICE

was competitively priced and readily available. Finally, 10% of the non-users of draff stated that they would need more information and advice on distillery by-products before making a decision to use them. The survey concluded that the trend towards larger scale enterprises and more mechanised systems had led to less flexibility and the need for forward planning - both financially and physically. Therefore unreliable supplies of a high priced product was not an attractive option to farmers. In order to resolve the marketing difficulties, distillers would have to evaluate their production system and move towards a more effective means of draff allocation between drying plants and farmers. The aim should be to allocate wet draff to the two outlets in proportions which yield the highest total financial returns. In order to achieve this, part of both allocations should be made on a long-term contractual basis. This new integrated marketing system should then be capable of satisfying the needs of the farmer by guaranteeing him a level of supply within reasonable limits.

Appraisal of agricultural trends and of draff use enables the integration and management of the discussed MDG/MSBN systems to be fully assessed.

CHAPTER 2 - MALT DISTILLERS GRAINS ENSILED WITH MOLASSED SUGAR BEET NUTS AS A CONCENTRATE REPLACER IN DAIRY COW DIETS

Introduction

Experiment 1 evaluates the replacement of proprietary concentrate with MDG ensiled with molassed sugar beet nuts (MSBN) in diets for dairy cows. Each of the two concentrate type feeds – proprietary concentrate and MDG/MSBN were fed at 3 levels of dry matter (DM) in order to make a direct comparison between the animal and financial performance achieved.

Materials and method

Animals and feeding

Twenty–four British Friesian autumn calving cows all in second lactation or more were used in this experiment. When the experiment commenced, the mean number of days calved was 43, ranging from 24 to 73 days. The mean milk yield and liveweight were 23.7 kg d^{-1} and 583 kg respectively. The experiment initiated with a 16 day covariance period during which all cows were offered 7 kg d^{-1} of proprietary concentrate in two feeds daily and silage ad libitum.

The 24 cows were allocated to 4 blocks of 6 cows so that cows within a block were as similar as possible in milk yield, liveweight and number of days after calving. Each block was then subdivided at random into 2 groups, one group was fed concentrate, the other group was fed MDG/MSBN/minerals (referred to as MDG mix), in the treatments listed :

LC – low concentrate	(3 kg DM)	LD – low MDG mix
MC – medium concentrate	(6 kg DM)	MD – medium MDG mix
HC – high concentrate	(9 kg DM)	HD – high MDG mix

Each sub-group of cows was then divided into six pairs and allocated to the changeover sequence shown below.

Period 1	3	3	6	6	9	9
2	6	9	3	9	3	6
3	9	6	9	3	6	3

The experiment consisted of 3 x 3 week periods and the cows were changed from one diet to another over a period of 4 days (the first four days of each period).

Silage was from the primary growth of a predominantly perennial ryegrass sward , harvested with a precision-chop forage harvester. Sulphuric acid was used as an additive at a rate of $3.5\ l\ t^{-1}$ before ensiling in an unroofed silo. In mid July , the MDG were mixed with MSBN (the mixture containing 18% MSBN on a fresh weight basis) and left overnight before being ensiled in an unroofed silo, using a 2-wheel drive tractor with dual wheels. The mineral mix was added to each individual cows feed prior to feeding at the rate of $50\ g\ kg^{-1}$ of the MDG/MSBN mixture DM and contained (in $g\ kg^{-1}$) calcium 100, phosphorus 50, magnesium 35, sodium- chloride 60 and potassium 150. The concentrate cube contained (in $g\ kg^{-1}$ fresh weight (FW)), barley 250, wheat 200, maize gluten 200, soya 150, wheat feed 80, molasses 50, fish meal 20, fat supplement 20 and mineral/vitamin supplement 30. Cows were group housed with access to individual feeding boxes fitted with transponder operated Calan gates (Broadbent, McIntosh and Spence, 1970).Water was freely available to all cows in the cubicle area. The concentrate and MDG mix were offered in 3 feeds daily at 8:30, 12:30 and 15:30h allowing 30 and 45 minute feeding periods for concentrate and MDG mix respectively.

Animal performance

Milk yields of individual cows were recorded twice daily on the last four days of each period and samples were taken for fat, protein and lactose analysis (Biggs, 1979). Milk samples were also taken at one milking, during the last 4 days of each period, for the determination of fatty acid profiles.

Liveweights were recorded at approximately 8:00 h on Monday, Wednesday and Friday in each week. Liveweight change was estimated from regression and metabolisable energy (ME) balance as ME intake – (ME required for maintenance + ME for milk production), (MAFF, 1975).

Feedstuffs were sampled daily in the last 4 days of each period for the determination of chemical composition and oven dry matter determinations were performed daily throughout the trial. Digestibilities of the feeds were determined by the in vitro techniques of Alexander (1969) and Alexander and McGowan (1969).

The ME concentration (MJ kgDM^{-1}) of the feeds were estimated using the following equations (J Dixon, personal communications):

$$\text{Silage ME} = ((\text{IVD} \times 0.907) + 6.03) \times 0.16$$

$$\text{Concentrate ME} = (0.14 \times \text{NCD}) + (0.25 \times \text{AHEE})$$

$$\text{MDG ME} = A + B \text{ when } A = \text{IVD} \times \frac{1000-\text{EE}}{1000} \times 0.0155$$

$$B = \text{EE} \times 0.9 \times 0.0342$$

where IVD is the in vitro digestible organic matter in the DM (g kg^{-1}), NCD is the neutral cellulase digestibility, AHEE is acid hydrolysed ether extract and EE is the ether extract. Dry matter intakes of silage ,proprietary concentrate and MDG mix were recorded during the last 4 days of each period.

Blood testing was performed on the last day of each period to examine blood levels of β–OH butyrate, urea, non–esterified fatty acids, total lipids, calcium, phosphorus and magnesium.

Design and Statistical Analysis

The design of the experiment was an incomplete changeover design consisting of 3 periods. Twenty-four cows were allocated to 4 blocks which were then allocated to 6 treatments in the sequence described earlier. The data was analysed using Genstat 4 and the degrees of freedom for the analysis of variance test are shown below.

Analysis of Variance (adjusted for covariance)

Variate – milk yield.

Source of Variance		Degrees of Freedom
Block effect	covariates	1
	residual	2
	total	3
Period effect		2
Block cow effect	feed	1
	covariates	1
	residual	18
	total	20
Block period effect	covariates	1
	residual	5
	total	6
Block cow period effect	level	2
	feed level	2
	residual	34
	total	38
	Grand Total	69

The variance ratio (F) was tested for significance with the use of F-tables where the degrees of freedom were as shown below:

	(v_1, v_2)
Feed	(1,18)
Level	(2,34)
Feed Level	(2,34)

Results

The average chemical composition of the silage, concentrate and MDG/MSBN are given in Table 2.1. The proprietary concentrate has a higher ME, DM and crude protein (CP) content than the MDG/MSBN. Mineral levels for the MDG/MSBN are considerably lower than for the proprietary concentrate (prior to mineral supplementation.)

Concentrate DM intake

Table 2.2 and Figure 2.2 show the dry matter intake (DMI) achieved when cows were fed concentrate – either in the form of a proprietary concentrate or MDG mix at levels of 3, 6 and 9 kg DM for each feed. The cows consumed all the proprietary concentrate offered at each level but consumed only 90%, 82% and 71% respectively of the 3, 6 or 9 kg DM on offer in the form of MDG mix. At the medium and high levels of feeding, the concentrate DMI's were significantly different for the two forms of concentrate. Cows on treatment HD consumed 2.4 kg DM less than cows on treatment HC while the difference was 1.1 kg DM at the medium level of feeding.

Silage DM intake

Silage DMI's for each treatment are shown in Table 2.2 and Figure 2.2. Silage DMI's are similar for treatments, LC, MC and HC showing no significant differences. The results for treatments LD, MD and HD show a reduction in silage DMI as MDG mix DMI increased – cows on treatment HD consumed 1.7 kg DM less silage than cows on treatment LD. There were no significant differences for silage DMI between the MDG mix and the proprietary concentrate treatments when fed at similar levels. The substitution rate (SR) between MC and HC was 0.11 and between LC and HC was 0.03. The SR's between LD and MD, between MD and HD and between LD and HD were 0.41, 0.53 and 0.46 consecutively. SR increased with the level of concentrate feeding for both forms of concentrate. Figure 2.1 shows the change in silage intake as the level of concentrate–type feed was increased. The graph illustrates a greater limitation of silage intake on MDG diets compared to concentrate diets.

Total DM intake

Total DMI results (see Table 2.2 and Figure 2.2) for treatments LC, MC and HC ranged from 12.5 kgDM d^{-1} at the low level of feeding to 18.1 kgDM d^{-1} at the high level of feeding. The total DMI's for the MDG mix treatments again showed an increase in trend from LD to HD. Treatments LD and MD were significantly different as were treatments LD and HD. Treatment HC and HD were significantly different but on comparing other treatment means for different feeds at the same level no significant differences were found for total DMI. Treatment HC had a mean total DMI of 18.1 kg d^{-1} which was 17% greater than the total DMI for treatment HD.

Milk yield

Table 2.3 and Figure 2.3 show a range in milk yield from 19.94 to 24.19 kg d^{-1} for treatments LC to HC and from 20.31 to 22.95 kg d^{-1} for treatments LD to HD. Treatments MC and MD differed significantly for milk yield. The differences in milk yield between different levels of the same feed were very highly significant.

Milk composition

The results for fat content (see Table 2.3 and Figure 2.4) show significant differences between the 2 concentrate-type feeds. The fat content results for proprietary concentrate treatments were on average 4.1 g kg^{-1} higher than the MDG mix treatment results. Fat yield results (see Table 2.3) show a steady increase from the low level of feeding to the high level of feeding for both concentrate-type feeds. Significant differences were apparent between treatments MC and MD and between treatments HC and HD. At the low level of feeding fat yield differences were however non-significant. Fat yield varied by almost 200 g d^{-1} between LC and HC and by 80 g d^{-1} between LD and HD – the fat yield for HC being 20% greater than for HD. Differences between the 2 feeds for fat yield were very highly significant except at the low level of feeding.

The protein yield for the 2 feeds differed by 64 g d^{-1} at the medium level of feeding and by 54 g d^{-1} at the high level of feeding. Milk lactose content results (see Table 2.3) show an increase from low to high levels of feeding for both concentrate–type feeds. Very highly significant differences for lactose yield were shown between different levels of the same feed for both MDG mix and proprietary concentrate treatments.

ME intake was calculated for each treatment and Table 2.2 shows a range from 138.1 to 211.9 MJ d^{-1} for proprietary concentrate treatments and a range from 143.2 to 163.0 MJ d^{-1} for MDG mix treatments. Differences in ME intake were highly significant for the medium and high level of feeding between the two concentrate–type feeds.

Crude protein (CP) intake results are shown in Table 2.2 and range from 2.2 to 3.3 kgDM d^{-1} for the proprietary concentrate treatments and from 2.1 to 2.5 kgDM d^{-1} for MDG mix treatments. Proprietary concentrate treatments differ highly significantly from MDG mix treatments for CP intake at the medium and high level of feeding.

Liveweight change was calculated from regression of weight on time and also by the ME balance method where ME balance considers ME intake – (ME required for maintenance + ME for milk production) (MAFF, 1975). Liveweight change results are shown in Table 2.4. There were no significant differences between feeds at the same level for liveweight change calculated by regression or by ME balance. Due to the inaccuracies involved in the estimation of the ME content of MDG/MSBN and the short time periods over which weight change was calculated by regression, the liveweight change results, calculated by the two methods stated, differ considerably. For experimental purposes weight change was monitored using the regression method with caution.

Blood analysis results are shown in Table 2.5. Total lipid concentration results were generally higher for MDG treatments – the difference between the MDG and concentrate treatments being very highly significant at feed level. Blood calcium level was higher (on average 6%) for MDG mix treatments, compared to concentrate treatments. The differences between feeds for blood calcium level were highly significant.

Results

Notes on tables 2.2 - 2.5

1 Values for treatments LC, MC and HC not sharing common superscripts (w, x) differ significantly ($P<0.05$).

2 Values for treatments LD, MD and HD not sharing common superscripts (p, q) differ significantly ($P<0.05$).

3 Superscripts a, b and c denote values for different feeds at any one level which do not differ significantly ($P<0.05$).

4 #SED when comparing means of different feeds at the same level.

5 Abbreviations for treatments.

LC - low concentrate (3 kgDM) LD - low MDG mix
MC - medium concentrate (6 kgDM) MD - medium MDG mix
HC - high concentrate (9 kgDM) HD - high MDG mix

Table 2.1 The chemical composition of feeds
(g kgDM^{-1} unless otherwise stated)

	Silage	**Concentrate**	**MDG/MSBN**
Oven dry matter (g kg^{-1})	170	853	296
Crude protein	160	202	187
Organic matter	915	914	928
DOMD* _in vitro_	690	-	610
Ether extract	-	42	63
Estimated ME (MJ kgDM^{-1})	10.9	12.6	10.8
Ca	5.5	8.9	5.7
P	3.6	7.3	5.4
Mg	2.1	8.2	2.0
Ammonia N (g kgtotal N^{-1})	122	-	-
pH	4.0	-	-

*DOMD - digestible organic matter in the dry matter.

NB - Mineral status of MDG mix prior to supplementation.

Table 2.2 Daily feed intake (kgDM d^{-1})

							SED/SIG			
	LC	MC	HC	LD	MD	HD	Feed	Level	Feed. Level	Level#
Proprietary concentrate	3.0^{a}	6.0	8.8	-	-	-	0.33***	0.24***	0.43***	0.34
MDG mix	-	-	-	2.7^{a}	4.9	6.4				
Silage	9.6^{aw}	9.7^{bw}	9.4^{cw}	10.4^{a}	9.5^{bp}	8.7^{cp}	0.51	0.39	0.67	0.57
Total	12.5^{a}	15.6^{b}	18.1	13.1^{a}	14.4^{bp}	15.0^{p}	0.76	0.46***	0.90**	0.68
*ME Intake (MJ d^{-1})	138.2^{a}	180.1	212.1	141.7^{a}	154.5^{p}	159.6^{p}	8.27**	4.76***	9.59***	6.97
*CP Intake (kg d^{-1})	2.2^{a}	2.8	3.3	2.1^{a}	2.4	2.5	0.13**	0.08***	0.15***	0.11

* estimated values
See notes on tables - page 42

Table 2.3 Milk production

	LC	MC	HC	LD	MD	HD	SED/SIG Feed	 Level	 Feed. Level	 Level#
Milk yield (kg d^{-1})	19.9^{a}	23.2^{w}	24.2^{bw}	20.3^{ap}	21.3^{p}	23.0^{b}	0.88	0.51***	1.05	0.72
Milk composition (g kg^{-1})										
Fat	42.8^{w}	42.3^{w}	43.5^{w}	39.5^{p}	38.7^{p}	38.2^{p}	1.47*	0.98	1.86	1.39
Protein	30.5^{w}	30.6^{aw}	31.8^{b}	30.0^{p}	30.8^{apq}	31.2^{bq}	0.39	0.46*	0.66	0.65
Lactose	48.1^{aw}	48.6^{bw}	48.7^{cw}	47.9^{ap}	48.0^{bp}	48.4^{cp}	0.38	0.32	0.52	0.45
Component yield (g d^{-1})										
Fat	855^{a}	984	1054	796^{ap}	823^{pq}	876^{q}	30.4***	26.7***	43.2	37.9
Protein	605^{a}	710	763	602^{a}	646	709	25.0	17.5***	32.1	24.7
Lactose	968^{a}	1130^{w}	1184^{bw}	974^{ap}	1027^{p}	1114^{b}	43.5	27.0***	53.5	38.3

See notes on tables - page 42

Table 2.4 Estimated liveweight change (kg d^{-1})

	LC	MC	HC	LD	MD	HD	SED/SIG Feed	Level	Level	Feed. Level#
Liveweight Change (calculated by regression)	0.71^{aw}	0.49^{bw}	0.73^{cw}	0.25^{ap}	0.70^{bq}	0.50^{cpq}	0.159	0.199	0.279	0.282
Liveweight Change (calculated by ME balance)	-0.52^{aw}	0.14^{bw}	0.99^{c}	-0.54^{ap}	-0.15^{bpq}	0.44^{cq}	0.304	0.370**	0.524	0.523

See notes on tables - page 42

Table 2.5 Blood analysis (m mol l^{-1} unless otherwise stated)

								SED/SIG			
	Range	LC	MC	HC	LD	MD	HD	Feed	Level	Feed. Level	Level#
B-OH Butyrate	<0.75	0.51^{aw}	0.49^{bw}	0.44^{cw}	0.43^{ap}	0.44^{bp}	0.45^{cp}	0.041	0.038	0.060	0.055
NEFA (m eq l^{-1})	0.1-0.7	0.32^{aw}	0.30^{bw}	0.35^{cw}	0.31^{ap}	0.33^{bp}	0.34^{cp}	0.047	0.045	0.070	0.064
Urea	2.0-6.6	5.00^{w}	4.96^{aw}	4.54	4.71^{q}	4.30^{ap}	4.57^{pq}	0.227	0.170	0.300	0.240
Total lipids (g l^{-1})	1.5-5.0	6.25^{aw}	5.36^{x}	5.64^{wx}	7.04^{ap}	7.25^{p}	7.25^{p}	0.532***	0.239	0.553	0.521
Ca	2.2-2.6	2.00^{w}	2.01^{w}	1.94	2.13^{p}	2.13^{p}	2.07	0.042**	0.028*	0.053	0.039
Mg	0.8-1.1	1.04^{aw}	1.00^{bw}	0.96^{cw}	1.03^{ap}	0.96^{bp}	1.01^{cp}	0.055	0.045	0.075	0.063
P	1.7-2.2	2.03^{aw}	1.89^{bw}	2.03^{cw}	2.07^{ap}	1.99^{bp}	2.00^{cp}	0.080	0.067	0.111	0.095

See notes on tables - page 42

Table 2.6A Oil content of feeds (EE g $kgDM^{-1}$)

Silage	35
MDG Mix	63
Concentrate	42

Table 2.6B

Amount of oil consumed in the diet (EE g cow^{-1} day^{-1})

Dietary oil content	**LC**	**MC**	**HC**	**LD**	**MD**	**HD**
Silage	336	340	329	364	333	305
MDG/MSBN	-	-	-	170	309	403
Concentrate	126	252	370	-	-	-
Total oil intake	462	592	699	534	642	708
Total DM intake kgDM	12.5	15.6	18.1	13.1	14.4	15.0
% oil in diet	3.7	3.8	3.9	4.1	4.5	4.7

Figure 2.1

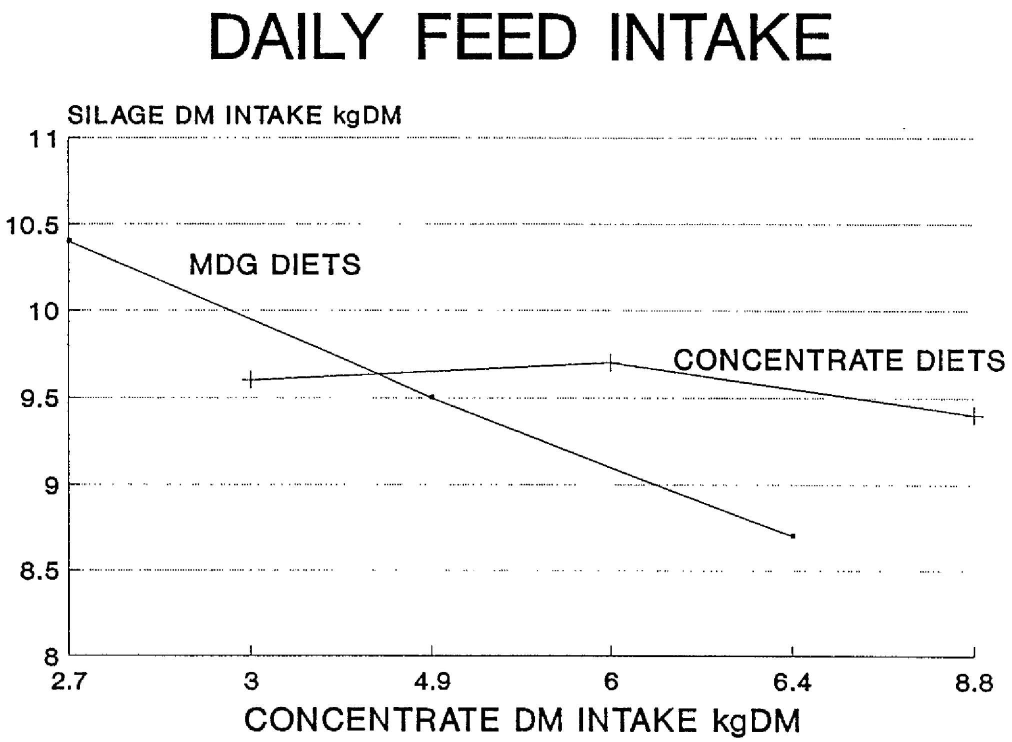
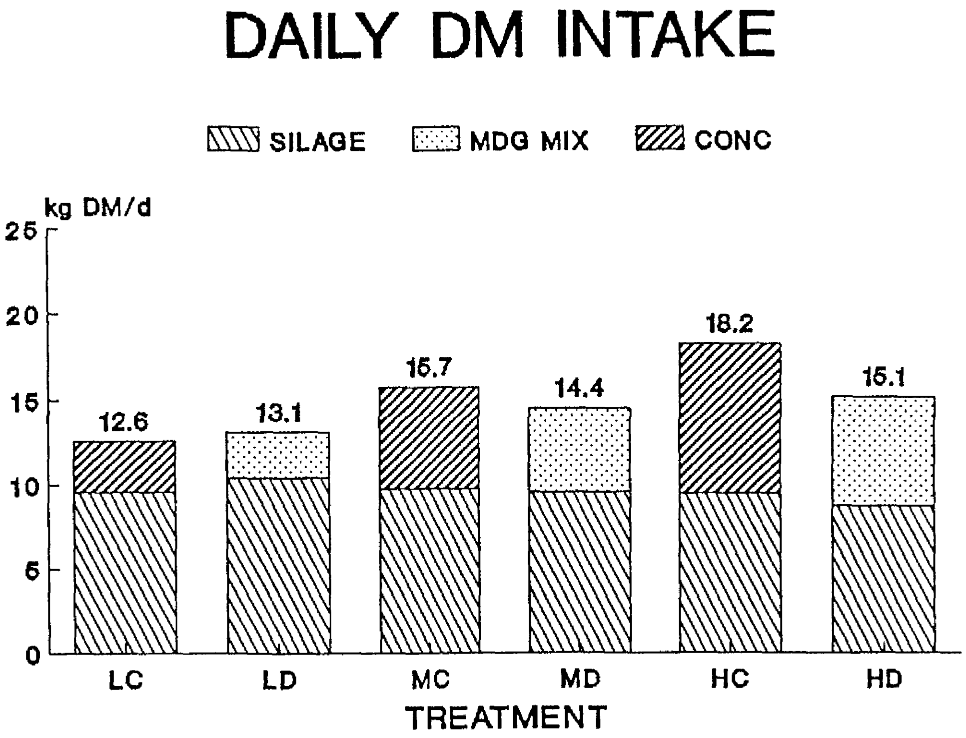

DAILY FEED INTAKE
SILAGE DM INTAKE kgDM
11
10.5
10
9.5
9
8.5
8
MDG DIETS
CONCENTRATE DIETS
2.7
3
4.9
6
6.4
8.8
CONCENTRATE DM INTAKE kgDM

Figure 2.2



DAILY DM INTAKE
SILAGE
MDG MIX
CONC
kg DM/d
25
20
15
10
5
0
12.6
13.1
15.7
14.4
18.2
15.1
LC
LD
MC
MD
HC
HD
TREATMENT

Figure 2.3

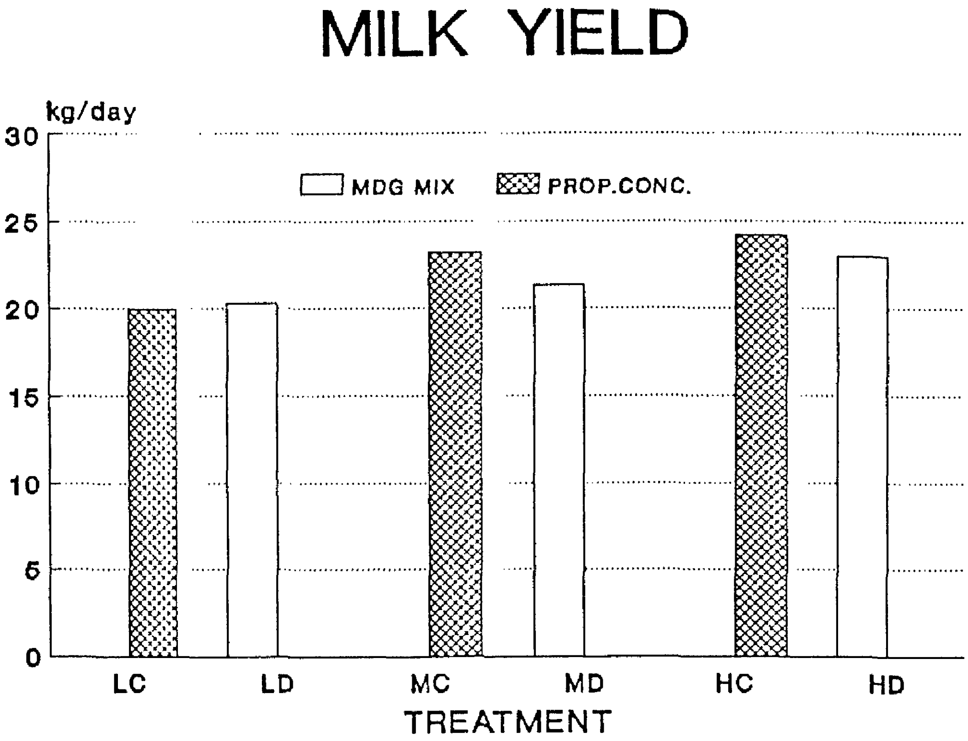
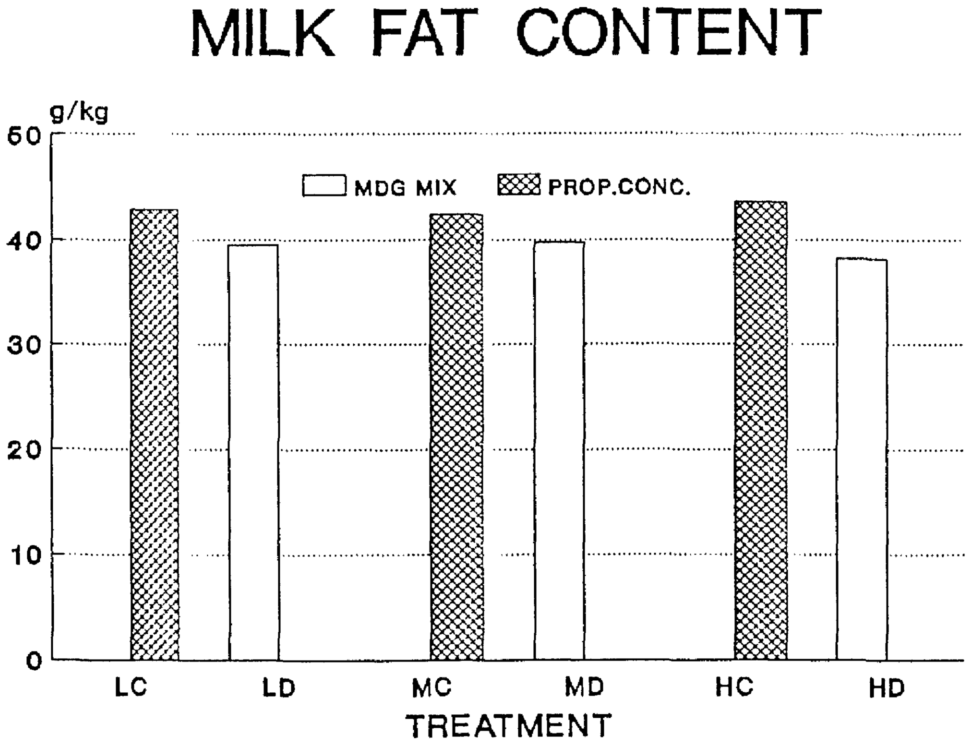


Figure 2.4



Discussion

Concentrate replacement experiment

In order to reduce variable costs in dairy farming, attempts have been made to replace proprietary pelleted concentrate with several by-products (see Table 1.5). The objective of experiment 1 was to evaluate MDG mix as a concentrate replacer in silage based diets for dairy cows.

DM intake

Daily DM intake results are shown in Table 2.2 and Figure 2.2. The DM intakes of MDG mix were lower than the corresponding intakes for concentrate treatments. This restriction of DM intake on treatments LD, MD and HD may be due to the bulky nature of MDG mix (see Figure 2.1). Research work by Hyslop et al (1990) which compared MDG ensiled on their own or with molassed sugar beet shreds (MSBS), as concentrate replacers in a complete diet feeding regime, indicated that total DM intake was greatest on the control treatment in which barley and soya were incorporated as the concentrate component of the complete diet. MDG mix is of a different physical form to proprietary pelleted concentrate and contains higher levels of fibre, both of which are factors of importance in physical regulation of VFI at rumen level (Campling, 1970; and Jorgensen, 1979). When MDG mix was fed to 0.34 of the total DM intake, milk yield and milk protein content were maintained and milk fat content was depressed by 3.6 g kg^{-1} compared to the appropriate concentrate treatment (MC). This level of feeding 0.34 of the total DM intake was higher than that achieved by Hyslop et al (1988) (see Table 1.5), possibly due to the use of MSBN as an absorbent resulting in improved silo fermentation and feeding value (Hyslop et al, 1989b), and also by the feeding system which was three feeds daily in comparison to two improving rumen conditions by providing a steady supply of nutrients for the rumen microbes.

The use of MSBN as an absorbent in the ensilage of MDG results in an increased intake of the ensiled feed by dairy cows. MSBN is a source of readily digestible fibre and MDG mix has therefore a higher digestibility than MDG ensiled on their own. The increased digestibility of MDG mix could result in a higher ruminal outflow rate and thus allow higher intakes of MDG mix compared to MDG fed alone. Hyslop et al (1990) reported an increased DM intake of 10% when MDG and MSBS were ensiled together, compared to storing the feeds separately and mixing prior to feeding.

The dilution properties of MSBN in the feeding of MDG mix are also important because of the dilution of dietary fat (see Tables 2.6A and 2.6B). The production of MDG at the distillery involves a water extraction process designed to remove the starch component from the parent cereal. MDG form the residue once the starch has been removed and contain increased concentrations of fat, protein and fibre. Compared to the parent cereal MDG can contain up to 100 g $kgDM^{-1}$ of oil. The unsaturated oil found in MDG depresses the activity of rumen bacteria leading to reduced digestibility, low intakes and poor performance (Lewis, 1991). Any dilution of this oil by MSBN then allows higher intakes.

Researchers have evaluated mineral supplementation as a means of counteracting the adverse effects of diets containing large amounts of oil on rumen function (Lewis, 1991; and El Hag and Miller, 1972). In-vivo digestibility trials with sheep showed that as the level of calcium supplementation was increased sheep consumed greater amounts of MDG. This increase in digestibility of the MDG may be attributed to the formation of insoluble calcium soaps. The formation of these soaps involves the removal of fatty acids from solution and therefore renders them inactive against rumen bacteria (Grainger, White, Baker and Stroud, 1957). The mineral specification and level of supplementation seemed satisfactory for this experiment as DM intakes were consistent with other workers' results considering all aspects of the experiment.

Animal performance

Milk yield and composition results are shown in Table 2.3 and Figures 2.3 and 2.4. Previous studies by Hyslop et al (1988 and 1990) showed that milk yields from MDG fed twice daily and later from MDG mix incorporated in a complete diet, were greater than milk yields from concentrate treatments at the same level of DM intake.

The milk yield results from experiment 1 were 23.2 and 21.3 kg d^{-1} for treatments MC and MD respectively. The bulk restricting factor imposed by the MDG mix resulted in the concentrate DM intake for treatment MD being 1.1 kgDM lower than the corresponding concentrate treatment (MC).

Milk yield, expressed in kg $kgDM^{-1}$ of the appropriate concentrate–type feed offered were 4.4 and 3.9 for treatments MD and MC respectively, showing an improved utilisation of dietary energy on treatment MD. On treatment HD only 0.71 of the concentrate DM offered was consumed and there was a reduction of 1.2 kg in milk yield compared to treatment HC. From the results present, when MDG mix is fed at a higher level than 0.34 of the total DM intake, milk yield is depressed due to a restriction in DM intake imposed by the physical capacity of the reticulorumen.

The trend of a reduction in milk fat content on MDG mix treatments (see Table 2.3) was shown in work reported by Hyslop. When MDG/MSBN formed 0.46 of the total DM intake of the complete diet offered, milk fat content was reduced by 3.1 g kg^{-1} compared to the complete diet containing barley and soya as the concentrate fraction of the ration (Hyslop et al, 1990). This depression in milk fat content which occurs when MDG mix diets are fed may be explained by the type of fat present in the MDG. The fat contains a high proportion of long chain fatty acids (LCFA) and is of a highly unsaturated nature. Storry (1972) reviewed the subject of nutritional effects on milk fat synthesis and composition and suggested that when dairy cow rations were supplemented with a LCFA source, there was a resulting increase in transfer of component acids to milk but not always a net increase in yield of total milk fat. A depression in mammary synthesis of short and intermediate chain fatty acids, brought about by a reduction in availability of the substrate, has been shown to cause a marked depression in milk fat yield. Lastly, recent research (Hyslop, unpublished data) suggests that milk containing altered fatty acid profiles may be inaccurately analysed by the automated milk–o–scan (infra–red) analyser. This is because the milk used to calibrate this machine usually contains the 'standard' fatty acid profile. Hyslop (unpublished data) compared the milk fat content results from duplicate milk samples analysed by the milk–o–scan and by the reference Gerber method. When MDG comprised 20–40% of diet DM, the milk–o–scan machine underpredicted the fat content by 3 g/kg. Further research is needed in this area to accurately quantify the underestimation occuring with the milk–o–scan machine. No significant difference was present between treatments MC and MD for milk protein content. Milk protein yield was reduced on treatment MD compared to MC because of the differences already discussed in milk yield.

The ME intake results shown in Table 2.2 suggest that the energy from MDG mix fed was utilised more efficiently than the energy from proprietary concentrate. The milk yields per MJ ME for treatments MC and MD were 0.13 and 0.14 kgMJ^{-1} respectively. It should, however, be considered that the assumptions involved in the process of analysing MDG for ME may lead to inaccurate results.

Financial performance

Assuming the feed costs shown and the SMMB milk pricing arrangements for the period October 1989 until December 1989 (shown in Table 2.7A) the financial performance of the cows on each diet has been calculated and the results are shown in Table 2.7B. Milk sales were on average 28p cow^{-1}day^{-1} greater for concentrate treatments than for MDG mix treatments. The average margin over purchased feed was 341p cow^{-1}day^{-1} on concentrate treatments and 375 cow^{-1}day^{-1} on MDG mix treatments, differing by 34p day^{-1} in favour of MDG mix feeding. This could be interpreted in practical terms by a saving of £7,480 when feeding MDG mix to 100 cows over a 220 day winter. The treatment of significance to practical agriculture was treatment MD which gave a margin over purchased feed of 367p cow^{-1}day^{-1} – a substantial return achieved by purchasing the MDG during the summer when the price was low.

The ensilage of the MDG with MSBN, in order to reduce DM losses, resulted in a palatable feed of high nutritive and economic value. Dairy farmers who were able to ensile the two feeds discussed could replace costly proprietary concentrate with MDG mix, successfully in terms of animal and financial performance, up to the level of 5 kgDM.

Table 2.7A Milk value and feed costs

Milk	SMMB Pool Price	19.8 ppl
	Hygienic Premium	+0.15 ppl
	Fat %	See Table 8B
	Protein %	All at pool price
Feed	MDG/MSBN/Minerals	10.5 p $kgDM^{-1}$
	Concentrate	18.6 p $kgDM^{-1}$
	Silage	9.0 p $kgDM^{-1}$

Table 2.7B

	Treatments					
	LC	**MC**	**HC**	**LD**	**MD**	**HD**
Yield (kg d^{-1})	19.9	23.2	24.2	20.3	21.3	23.0
Yield (l d^{-1})	19.3	22.5	23.5	19.7	20.6	22.3
Fat %	4.28	4.23	4.35	3.95	3.87	3.82
Protein %	3.05	3.06	3.78	3.00	3.09	3.12
Fat Payment ppl	0.77	0.77	0.88	0.44	0.33	0.33
Payment ppl	20.72	20.72	20.83	20.39	20.28	20.28
Milk sales p $d^{-1}cow^{-1}$	400	466	490	402	418	452
Intake (kgDM d^{-1})						
Concentrate	3.0	6.0	8.8	2.7	4.9	6.4
Silage	9.6	9.7	9.4	10.4	9.5	8.7
Feed Costs (p d^{-1})						
Concentrate	55.8	111.6	163.7	28.4	51.5	67.2
Silage	86.4	87.3	84.6	93.6	85.5	78.3
Total	142.2	198.9	248.3	120.0	137.0	145.5
Margin over purchased feed (p d^{-1})	344	354	326	374	367	385
Margin over all feed (p d^{-1})	258	267	242	282	281	307

CHAPTER 3 - MALT DISTILLERS GRAINS ENSILED WITH MOLASSED SUGAR BEET NUTS AS A COMPLEMENT AND REPLACER TO SILAGE IN DAIRY COWS

Introduction

Experiment 2 considers the use of MDG mix as a complement and replacer for silage. MDG mix was incorporated with chopped straw and fed ad-lib as a forage for dairy cows. The performance of dairy cows fed 3 different forages:

1 MDG/MSBN/straw mix
2 MDG/MSBN/straw/silage mix
3 Silage,

was monitored in order to evaluate the rations offered.

Materials and methods

Animals and feeding.

Fifteen British Friesian autumn calving cows all in second lactation or more were used in this experiment. The average number of days calved was 126 with a range of 108 to 142 days. The 15 cows were allocated to five blocks of three cows so that cows within a block were as similar as possible in milk yield, liveweight and number of days after calving. The mean milk yield and liveweight were 19.8 kg d^{-1} and 557 kg respectively at the start of the trial. The experiment consisted of three periods of 4 weeks duration and was of a complete changeover design. The treatments are listed below:

S	ad libitum silage plus 6 kg d^{-1} concentrate
MDG	ad libitum MDG/MSBN/straw/minerals plus 6 kg d^{-1} concentrate
S/MDG	a 50:50 mix (on a DM basis) of MDG mix and silage ad libitum plus 6 kg d^{-1} concentrate.

Cows were changed from one diet to another over a period of four days (the first four days of each period). The silage used in this experiment was harvested and ensiled using similar methods to those discussed in chapter 2. For information on ensilage of MDG see chapter 2.

The mix for treatment MDG was prepared daily using a Cormall A/S feed mixer and consisted of (in g kg^{-1} fresh weight (FW)) MDG/MSBN 929, chopped straw 63 and minerals 8. The MDG mix had a DM, metabolisable energy (ME) and crude protein (CP) level of 328 g kg^{-1}, 10.00 MJ $kgDM^{-1}$ and 153 g kg^{-1} DM respectively. The mineral mix was included in the MDG mix at 25 g kg^{-1} of the MDG/MSBN DM and contained in (g kg^{-1}) calcium 100, phosphorus 50, magnesium 35, sodium chloride 60 and potassium 150. The concentrate cube contained (g kg^{-1} FW), barley 250, wheat 200, maize gluten 200, soya 150, wheat 80, molasses 50, fish meal 20, fat supplement 20 and mineral vitamin supplement 30 and was offered in 2 feeds daily at 10:30 and 15:30. Housing and feeding facilities were as for experiment 1.

Animal performance

Milk yields of individual cows were recorded twice daily on the last four days of each period and samples were taken for fat, protein and lactose analysis (Biggs, 1979). Milk samples were also taken at one milking during the last four days for the determination of fatty acid profiles.

Liveweights were recorded at approximately 11:00 h on Monday, Wednesday and Friday in each week. Liveweight change was estimated by regression and ME balance as ME intake − (ME required for maintenance + ME for milk production), (MAFF, 1975).

The individual ingredients of the MDG mix, the silage and the concentrate were all sampled daily in the last four days of each period for the determination of chemical composition and oven dry matter determinations were performed daily throughout the trial. Digestibilities of the feeds were determined by in vitro techniques of Alexander

(1969) and Alexander and McGowan (1969).

The ME concentration (MJ kg DM^{-1}) of the feeds were estimated using the following equations (J Dixon, personal communication):

$$\begin{aligned} \text{Concentrate ME} &= (0.14 \times \text{NCD}) + (0.25 \times \text{AHEE}) \\ \text{Silage ME} &= (\text{IVD} \times 0.907 + 6.03) \times 0.16 \\ \text{Straw ME} &= (\text{IVD} \times 1.207 - 10.21) \times 0.15 \\ \text{MDG ME} &= A + B \text{ when} \end{aligned}$$

$$A = \text{IVD} \times \frac{1000 - \text{EE}}{1000} \times 0.0155$$

$$B = \text{EE} \times 0.9 \times 0.0342$$

where IVD is the in vitro digestible organic matter in the DM (g kg^{-1}), NCD is the neutral cellulase digestibility, AHEE is the acid hydrolysed ether extract and EE is the ether extract. Silage, MDG mix, silage/MDG mix and concentrate DM intakes were recorded during the last four days of each period.

Blood testing was performed on the last day of each period to examine blood levels of β–OH butyrate, urea, non–esterified fatty acids, total lipids, calcium, phosphorus and magnesium.

Design and Statistical Analysis

The design of the experiment was a complete changeover design consisting of 3 periods. Fifteen cows were allocated to 5 blocks which were then allocated to 3 treatments. All data was analysed using Genstat 4 and the degrees of freedom for the analysis of variance test are shown below.

Analysis of Variance
Variate – silage DM intake.

Source of Variation		Degrees of Freedom
Block effect		4
Period effect		2
Block cow effect		9 (1 missing value)
Block period effect		8
Block cow period effect	treatment	2
	residual	13 (5 missing values)
	total	15
	Grand Total	38

The variance ratio (F) was tested for significance with the use of F–tables where the degrees of freedom were as shown below:

	(v_1, v_2)
treatment	(2,13)

Results

The chemical composition of the individual feeds and mixes are given in Tables 3.1A and 3.1B. The MDG/MSBN had a higher DM than the silage. The silage had an ME of 11.4 MJ kgDM^{-1} which was 0.4 MJ kgDM^{-1} greater than the ME estimation for the MDG/MSBN. The crude protein levels for silage and MDG/MSBN were similar.

DM intakes

Cows on each of the treatments consumed all of the 5.1 kg DM concentrate offered. The forage DM intakes for treatments S, S/MDG and MDG were 8.3, 11.2 and 14.2 kg DM respectively (see Table 3.2 and Figure 3.1). The forage DM intake was increased by 35% from treatment S to treatment S/MDG and by a further 27% from treatment S/MDG to treatment MDG. Total DM intake for treatments S, S/MDG and MDG were 13.4, 16.3 and 19.3 kg DM respectively – the differences between which, were very highly significant.

Milk yield and composition

The average milk yield for each treatment is shown in Table 3.3. There was a range in milk yield from 17.0 kg d^{-1} for treatment S to 20.0 kg d^{-1} for treatment MDG. Treatments S/MDG and MDG differed significantly from treatment S for milk yield but were not significantly different from each other. The results for fat content (see Table 3.3) show significant differences between treatments S and MDG and between treatments S/MDG and MDG. The fat content for treatment MDG was 38.6 g kg^{-1} which was on average 3.1 g kg^{-1} lower than the two other treatments. Protein content results showed a gradual increase from treatment S to treatment MDG although there were no significant differences between treatments, a trend also illustrated in lactose content results. Component yield results are shown in Table 3.3 . Results for fat yield range from 694 to 790 g d^{-1} for treatments S and S/MDG respectively. Protein yield results show that treatment S/MDG and MDG are significantly different from treatment S but are not significantly different from each other. The protein yield for treatment S is on average 96.5 g d^{-1} lower than the results for other treatments. The same trend is illustrated in the lactose yield results, the reduction being 134 g d^{-1} for treatment S.

ME intake was calculated for each treatment and Table 3.2 shows a range from 162 to 196 MJ d^{-1}. There was no significant difference between the ME intakes for treatments S and S/MDG which were on average 27 MJ lower than the ME intake for treatment MDG (see Table 3.2) . Crude protein intake results are shown in Table 3.2. The differences between treatment means were very highly significant and the trend was to gradually increase with the level of MDG mix being fed.

Table 3.4 shows liveweight change results calculated by regression and also by the ME balance method. The former method shows no significant differences between treatments S/MDG and MDG while the latter method shows no significant differences between treatment S and S/MDG

Blood analysis results are shown in Table 3.5. The differences between treatments for total lipid content and for urea content were highly significant and very highly significant respectively, the trend being to increase with the level of MDG mix fed (all total lipid results were above the normal bovine range given). The level of non-esterified fatty acids (NEFA) in the blood was significantly higher for treatment MDG than for the other two treatments although all NEFA results were within the normal bovine range.

Table 3.1A The chemical composition of feeds
(g $kgDM^{-1}$ unless otherwise stated)

	Silage	**MDG/MSBN**	**Straw**	**Concentrate**
Oven dry matter (g kg^{-1})	182	288	821	861
Crude Protein	152	181	30	201
Organic matter	928	934	956	909
DOMD* in vitro	725	616	44	–
Ether extract	–	69	–	57
Estimated ME (MJ $kgDM^{-1}$)	11.4	11.0	6.5	12.7
Ca	5.3	5.1	2.2	10.7
P	3.4	2.9	0.7	7.8
Mg	2.0	1.5	0.8	8.2
Ammonia N (g kgtotal N^{-1})	114	–	–	–
pH	3.8	–	–	–

*DOMD – digestible organic dry matter in the dry matter

Table 3.1B The estimation of the chemical composition of the mixes fed

	MDG Mix	**MDG/Silage Mix**
Oven Dry Matter (g kg^{-1})	328	235
Estimated ME (MJ $kgDM^{-1}$)	10.0	10.7
Crude Protein (g $kgDM^{-1}$)	153.0	152.5
Ca (g $kgDM^{-1}$)	6.5	5.9
P (g $kgDM^{-1}$)	3.5	3.5
Mg (g $kgDM^{-1}$)	2.1	2.1

Table 3.2 Daily feed intake (kgDM d^{-1})

	Treatment			
	S	**S/MDG**	**MDG**	**SED**
Concentrate	5.1	5.1	5.1	
Forage	8.3	11.2	14.2	0.48***
Total	13.4	16.4	19.3	0.48***
*ME intake (MJ d^{-1})	162^a	176^a	196	8.1*
*CP intake (kg d^{-1})	2.3	2.7	3.2	0.08***

* estimated values.

Values not sharing the same superscripts differ significantly ($P<0.05$).

Table 3.3 Milk production

	Treatment			
	S	**S/MDG**	**MDG**	**SED**
Milk yield (kg d^{-1})	17.0	19.4^{a}	20.0^{a}	0.56***
Milk composition (g kg^{-1})				
Fat	42.0^{a}	41.4^{a}	38.6	1.29*
Protein	33.8^{a}	34.1^{a}	34.2^{a}	0.37
Lactose	47.0^{a}	47.8^{a}	47.3^{a}	0.42
Component yield (g d^{-1})				
Fat	694^{a}	790^{b}	761^{ab}	36.5
Protein	552	638^{a}	659^{a}	23.2***
Lactose	785	911^{a}	927^{a}	29.2***

Values not sharing the same superscripts differ significantly ($P<0.05$)

Table 3.4 Estimated liveweight change (kg d^{-1})

	Treatment			
	S	**S/MDG**	**MDG**	**SED**
Liveweight Change (calculated by regression)	0.12	0.90^{a}	0.89^{a}	0.110***
Liveweight Change (calculated by ME balance)	0.55^{a}	0.51^{a}	1.09	0.225*

Values not sharing the same superscripts differ significantly ($P < 0.05$).

Table 3.5 Blood analysis (m mol l^{-1} unless otherwise stated)

	Normal Bovine Range	S	S/MDG	MDG	SED
β OH Butyrate	<0.75	0.46^a	0.47^a	0.36^a	0.055
NEFA (m eq l^{-1})	0.1-0.7	0.16^a	0.22^a	0.36	0.055***
Urea	2.0-6.6	3.55	4.00	5.14	0.166***
Total lipids (g l^{-1})	1.5-5.0	5.95	6.74	8.31	0.313**
Ca	2.2-2.6	2.16^a	2.24^a	2.16^a	0.042
Mg	0.8-1.1	0.93^a	0.92^a	0.87^a	0.048
P	1.7-2.2	1.81^a	1.93^a	1.87^a	0.061

Values not sharing the same subscripts differ significantly ($P < 0.05$).

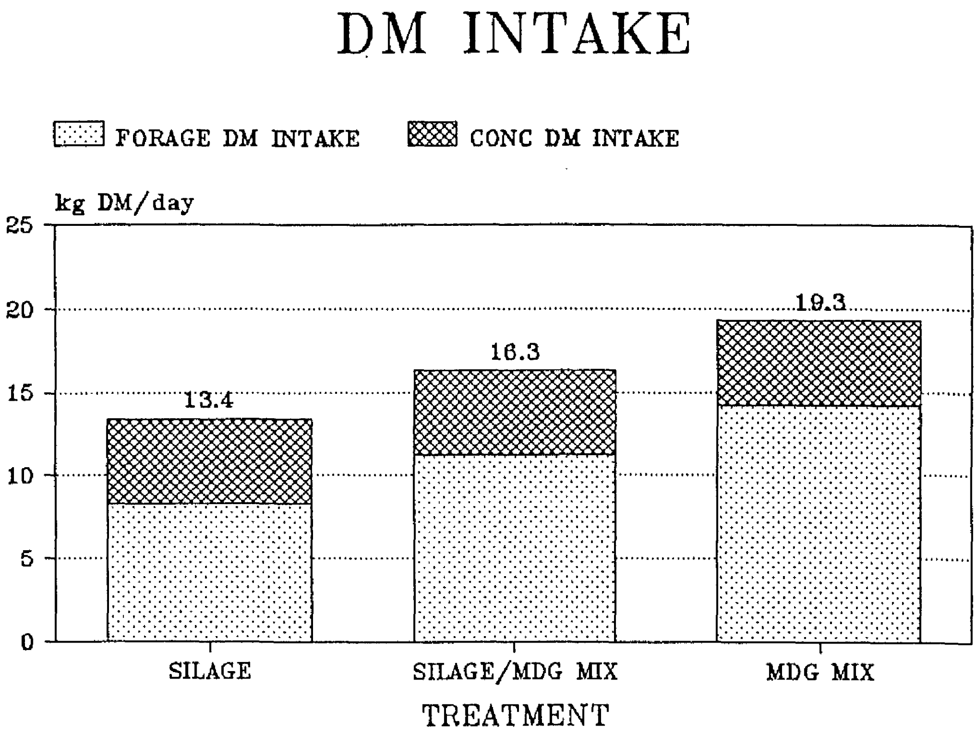
Table 3.6A Oil content of feeds (g $kgDM^{-1}$)

Silage	35
MDG/MSBN	69
Straw	14
Concentrate	57

Table 3.6B Amount of oil consumed in the diet ($g\ cow^{-1}\ d^{-1}$)

	S	S/MDG	MDG
Silage	291	196	-
MDG/MSBN	-	311	787
Straw	-	13	34
Concentrate	291	291	291
Total oil intake	582	811	1112
Total DM intake ($kg\ d^{-1}$)	13.4	16.4	19.3
% oil in diet	4.3	5.0	5.8

Figure 3.1


DM INTAKE
FORAGE DM INTAKE
CONC DM INTAKE
kg DM/day
25
20
15
10
5
0
13.4
16.3
19.3
SILAGE
SILAGE/MDG MIX
MDG MIX
TREATMENT

Discussion

Forage replacement

Due to the environmental problems associated with silage making and storage, there has been more interest in the use of alternative forages. The purpose of experiment 2 was to evaluate MDG mix as a supplement to, or replacement for, silage in dairy cow diets.

DM intake

The DM intake results shown in Table 3.2 and Figure 3.1 show an increase in forage DM intake with an increase in the amount of MDG mix on offer. The response to supplementation and complete substitution of grass silage with MDG mix was an increase in total DM intake by 22% from treatment S to treatment MDG/S and by 44% from treatment S to treatment MDG. A total DM intake of 19.3kg on treatment MDG was comparable with the augmented intake results on a complete diet feeding system (Hyslop et al, 1989b). The increase in DM intake on treatments MDG/S and MDG were accompanied by an increase in ME intake (see Table 3.2). Roberts (1988) reported a similar phenomena when feeding a forage consisting of straw mix and silage on which a total DM intake of 17.0 kg d^{-1} and an ME intake of 190 MJ d^{-1} was achieved. Researchers Aston, Daley and Gibbs (1987) fed a 1:1 mix of silage and brewers grains in a partial storage feeding regime and found that cows fed this mix had increased total DM intakes of 2.0 kg $cow^{-1}day^{-1}$, compared to cows fed silage alone overnight.

The effect of the physical form and chemical composition of MDG mix and other distillery by–products, on rumen regulatory factors controlling VFI may explain the high DM intakes shown on treatments MDG and S/MDG. Forage particle size has been found to affect the flow of fibre through the rumen (Wilkinson et al, 1978; Jorgensen, 1979; and Dewysen et al, 1978). The source of MDG is barley, which during distillation undergoes a rigorous mashing extraction process resulting in the production of MDG which characteristically have a very small particle size. Silage, when precision chopped, may still be of length 3.5 cm and so is classed as a long fibre. The chopped straw incorporated in the MDG mix was of length 5–7 cm, but the mix contained only 6% straw on a fresh weight basis. Although particle size was not measured in any of the experiments, considering the sources and processing techniques, MDG mix would most likely have a smaller particle size than the silage fed.

Wilkinson et al (1979) reported increased DM intakes of maize silage by young bulls when the chop length was decreased from 33.3mm to 7.67mm. This trend of increased DM intake with reduced forage particle size was also shown in this experiment. The presence of the MSBN, a source of readily fermentable fibre, could have contributed to the improved performance achieved on treatments MDG and S/MDG, as the MDG mix would be fermented in the rumen irrespective of the increased forage passage rate. Campling (1970) presented a theory regarding the physical regulation of VFI which suggested that VFI was limited by the capacity of the reticulorumen and the rate of disappearance of digesta from this organ. The reduced particle size and higher DM content of the MDG mix would then theoretically pose less of a restriction on the reticulorumen, allowing larger quantities of DM into the organ before eating ceased. Once present in the reticulorumen, the rate of passageway of the digesta is dependent on chemical composition of the food eaten (Van Soest, 1965). Compared to grass silage, barley has a low fibre content and so MDG mix is likely to pass through the reticulorumen quicker than grass silage, of which the cell–wall component would represent a higher proportion and would not be so rapidly fermented. Due to the physical and chemical composition of MDG mix, higher DM intakes are allowed by rumen regulatory factors. McDonald et al (1990) reported that a positive relationship exists between the voluntary intake of forages and forage DM content. The DM of forages fed on treatments S, S/MDG and MDG were 182, 235 and 328 g kg^{-1} respectively. Phipps (1990) reported an increased DM intake of 1.5kg in dairy cow diets when the DM of the maize silage fed increased from 230 to 300 g kg^{-1}. The results from this experiment showed an increased intake of 2kg DM when forage DM content increased from 235 to 328 g kg^{-1}. The relationship suggested by McDonald et al (1990) is supported by the increased intakes in experiment 2 which are also comparable to Phipps (1990) work with maize silage.

Animal performance

The milk yields shown in Table 3.3 are satisfactory for cows 18 weeks into lactation. An average increase of 2.7 kg d^{-1} was achieved on treatments S/MDG and MDG compared to treatment S. Although there was a 2.9kg DM increase in intake between treatments S/MDG and MDG, there was no significant difference in milk yield between the 2 treatments. The extra energy consumed in treatment MDG may have been partitioned to liveweight gain (see Table 3.4) which would be feasible at this late stage of lactation. If the experiment was repeated with cows in early lactation, perhaps the high DM intakes for treatment MDG would be accompanied by higher milk yields and lower levels of liveweight gain. The increased level at liveweight gain on treatment MDG may be an advantage to farmers wishing to improve the cows' body condition prior to calving.

An experiment carried out early in the grazing season by Aston et al (1987), where autumn calving cows were partial storage fed on a 1:1 mix of silage and brewers grains or silage on its own, showed a response in milk yield of an increase of 4 kg $cow^{-1}day^{-1}$. Unlike experiment 2, Aston reported no significant reduction in milk fat content on the by-product treatment compared to the silage fed cows. Milk composition results for experiment 2 are shown in Table 3.3. The reduction in milk fat content reported in experiment 1 (3.6 g kg^{-1}) is again present in experiment 2 (3.4 g kg^{-1}) between treatments S and MDG. MDG constitute 0.32 of the total DM of the diet on treatment MD in experiment 1, and 0.19 of the diet on treatment MDG in experiment 2. As already discussed in experiment 1, the unsaturated nature of the fat present in MDG may have an adverse effect on rumen function, and it would be expected that the higher the level of MDG in the diet, the greater the effect. Dietary oil contents for experiment 1 are shown in Tables 3.6A and B. The MDG fed in experiment 1 were offered 3 times daily compared to an ad-libitum feeding regime in experiment 2. The rumen microbes were subjected to high levels of fat in a short period of time in experiment 1 which resulted in depressed activity to a slightly greater extent than in experiment 2.

Milk fat content is also dependent on other dietary characteristics such as physical form and fibre content. Diets in which the roughage fraction is ground or of a low particle size and diets containing a low fibre component, have been reported to result in a reduction in milk fat yield known as 'the low milk fat syndrome' (Storry, 1972). This depression in milk fat content arises due to changes in rumen metabolism caused by these low fibre diets. Rumen pH decreases resulting in a change in the microbial population and so the pattern of rumen fermentation becomes altered. Cellulose digestion virtually ceases and rumen volatile fatty acids are produced in different proportions due to the impact of low fibre diets. The reduced rumen production of acetate and butyrate contribute to reduced mammary uptake of milk fat precursors and fatty acid utilisation becomes directed towards adipose tissue deposition, rather than secretion in milk fat (Storry, 1972). Diets containing MDG have a lower fibre content than silage diets and as already discussed, may be of reduced particle size. It is therefore likely that due to these dietary characteristics, the milk fat content is depressed on treatment MDG for the reasons discussed.

The draff mix was originally formulated to have a similar ME content as an average quality silage. For formulation purposes a 'standard' value of 11.8 MJ kgDM^{-1} was assumed for the MDG/MSBN giving a mix with an ME of 10.7 MJ kgDM^{-1} which was comparable with average silage ME values. The actual ME of the MDG/MSBN used in this experiment was 11.0 MJ giving an MDG mix with ME content - 10.0 MJ kgDM^{-1} which was 1.4 MJ kgDM^{-1} lower than the silage fed. Dry matter intakes were increased for treatments S/MDG and MDG and this more than compensated for the lower energy content of the mixes.

Financial performance

Milk value and feed costs are shown in Table 3.7A and the financial performance of the cows on each treatment is shown in Table 3.7B. Milk sales ranged from 339 on treatment S to 391p cow^{-1}day^{-1} on treatment MDG. The average margin over all feed costs were 169, 186 and 162p cow^{-1}day^{-1} for treatments S, S/MDG and MDG respectively. Treatment S/MDG was the most economically viable treatment and had a margin over all feed costs which was on average 21 p cow^{-1}day^{-1} greater than the other two treatments. No value was placed on liveweight gain in the financial performance data which explains the low margins for treatment MDG. The use of MDG mix to complement silage as a forage for dairy cows could enable farmers to save up to £4,092 over a 220-day winter for a herd of 100 cows.

Experiment 2 has proved the flexibility of MDG mix as a feed for dairy cows. The use of MDG mix as a complement or as a replacer for silage reduces the area needed for silage making and presents the farmer with 3 options. Silage could be made earlier in the season when the quality is high, the use of nitrogen fertiliser could be reduced, or the released land could be used for an alternative enterprise.

Table 3.7A Milk value and feed costs

Milk	SMMB Pool Price	19.8 ppl
	Hygienic premium	+0.15 ppl
	Fat %	see Table 6B
	Protein %	see at pool price
Feed	MDG/MSBS/minerals/straw	9.2 p kgDM^{-1}
	Concentrate	18.6 p kgDM^{-1}
	Silage	9.0 p kgDM^{-1}

Table 3.7B Financial Performance

	Treatments		
	S	S/MDG	MDG
Yield (kg d^{-1})	17.0	19.4	20.0
Yield (l d^{-1})	16.5	18.8	19.4
Fat %	4.20	4.14	3.86
Protein %	3.38	3.41	3.42
Composition payment (ppl)	0.77	0.66	0.33
Payment (ppl)	20.57	20.46	20.13
p cow^{-1} d^{-1}	339	385	391
Intake (kgDM d^{-1})			
Concentrate	5.13	5.13	5.13
Forage	8.25	11.22	14.17
Feed costs (p d^{-1})			
Concentrate	95.4	95.4	95.4
Forage	74.3	103.0	133.0
Total	169	199	229
Margin over concentrate (p d^{-1})	244	290	295
Margin over all feed (p d^{-1})	169	186	162

CHAPTER 4 – MALT DISTILLERS GRAINS ENSILED WITH MOLASSED SUGAR BEET NUTS AS THE SOLE DIETARY CONSTITUENT FOR BULL BEEF CATTLE

Introduction

The final experiment assesses the use of MDG mix as the sole dietary constituent in a bull beef finishing ration. This experiment allowed the comparison of two finishing systems (1) a conventional silage/concentrate system and (2) an ad-libitum MDG system, in terms of animal production and cost effectiveness.

Materials and methods

Animals and feeding

Twenty British Friesian bulls were used in this experiment which was of a continuous design. The calves were 4 months old when the trial started and had a mean liveweight of 124kg (SED 26.6). The calves were paired according to liveweight and date of birth and then allocated at random to one of two treatments.

The treatments were:

Treatment S – ad-libitum silage plus 3 kg concentrate.
Treatment MDG – ad-libitum MDG/MSBN/minerals.

The calves allocated to treatment MDG underwent a 3 week changeover period from a silage-based diet, fed prior to the experiment, to the MDG diet. Concentrate was fed at 3 kg in week 1 and was gradually reduced by 1 kg per week. A 50:50 mix of MDG and silage was fed in week 1 to ensure no digestive upsets. During the experimental period the concentrate on treatment S was fed in two feeds daily at 8.30 and 16.30 and all forages were offered once daily at 8.30. The concentrate fed contained in (g kg^{-1} FW) barley 810, soya 120, molasses 45 and minerals 25.

The silage used in the experiment was partly from the first cut of a predominantly perennial ryegrass sward which was harvested initially on the 22–25th May 1989. The herbage was wilted for 6–12 hours before being harvested with a precision chop forage harvester. Sulphuric acid was used as an additive at the rate of 3.5 $l\ t^{-1}$ before ensiling in an unroofed silo. Later in the experiment second and third cut silage was fed. This silage was made from the same sward type using similar techniques.

The MDG mix was ensiled and stored in exactly the same way as experiments 1 and 2. The mineral mix was also the same and was supplemented at the rate of 50 $g\ kg^{-1}$ of the MDG/MSBN DM. The minerals were mixed with draff/MSBN in the trough.

Initially the calves were housed in straw bedded pens in groups of 5. After the first month of the trial the calves were moved to pens with sloped floors (The Orkney system) where a minimum amount of bedding was given in the form of sawdust. The calves remained in the same groups of 5 throughout the trial as any mixing of pens may have resulted in fighting between bulls.

Animal performance

The bulls were weighed weekly and the mean liveweight gain for each treatment was calculated over the experimental period. The bulls were sold live at a local market when they reached 500 kg as the target slaughter weight was 475 kg and the bulls were found to lose 20–25 kg on the way to market.

Dry matter intake was recorded twice weekly and all feeds were sampled for chemical composition on a monthly basis throughout the experiment. Digestibilities of the feeds were determined by in vitro techniques of Alexander (1969) and Alexander and McGowan (1969). The ME concentration (MJ $kgDM^{-1}$) of the feeds was estimated using the equations already discussed in experiments 1 and 2.

Design and Statistical Analysis

Twenty bulls were paired and allocated to 2 treatments. The experiment was of a continuous design and continued until all bulls were slaughtered.

Analysis of Variance
Variate – mean

Source of Variation	Degrees of Freedom
Diet	1
Residual	17 (1 missing value)
Total	18

Results

The chemical composition of the individual feeds are shown in Table 4.1. The MDG/MSBN mixture had a higher DM at 287 g kg^{-1} than the silage at 192 g kg^{-1}. This mixture had also a higher crude protein content than the silage fed – differing by 30 g $kgDM^{-1}$. The estimated ME content of the MDG/MSBN was 0.4 MJ $kgDM^{-1}$ lower than the silage.

Intake

Average total DM intake shown in Table 4.2 was 6.3 kg DM per day for bulls fed MDG/MSBN and 5.9 kg DM per day for bulls fed the silage/concentrate diet. The total DM intake for treatment S consisted of 2.5 kg DM per day of concentrate and 3.4 kg DM per day of silage. Bulls on treatment MDG consumed 7% more DM than bulls on treatment S. Figure 4.1 shows the average DM intake of the bulls on each treatment over a 5 month period. This graph shows that the bulls on treatment MDG reached their maximum level of DM intake at 8 months – on average 1 month earlier than the silage/concentrate fed bulls. Freshweight intake as a percentage of liveweight is shown in Figure 4.2. Generally, freshweight as a percentage of liveweight was highest in the first 3 months of the period shown on the graph for MDG fed bulls. This parameter was highest between months 7 to 9 for the silage/concentrate fed bulls.

Liveweight gain

The liveweight gain for the bulls on treatments MDG and S were 1.56 and 1.35 kg d^{-1} respectively (see Table 4.2 and Figure 4.3). These results were calculated on the basis of the mean liveweight gain of bulls on each treatment up to the date on which the first bull was slaughtered. This difference in liveweight gain was significant ($P<0.05$). Bulls fed the MDG mix diet gained 1.47 kg per week more than bulls fed the silage/concentrate diet.

This increase in liveweight gain on treatment MDG resulted in the bulls finishing on average 3 weeks earlier than silage/concentrate fed bulls.

Table 4.1 The chemical composition of feeds
(g kgDM^{-1} unless otherwise stated)

	Silage	**Concentrate**	**MDG/MSBN**
Oven dry matter (g kg^{-1})	192	846	287
Crude protein	164	137	194
Organic matter	926	926	932
DOMD* *in vitro* ME	75.6	-	70.2
Ether extract	-	17.5	64.0
Estimated ME (MJ kgDM^{-1})	11.0	12.5	11.4
ME *in vivo* (MJ kgDM^{-1})	11.7	-	11.2
Ca	6.5	7.7	5.7
P	3.4	6.1	3.5
Mg	2.7	3.2	2.0
Ammonia N (g kg total N^{-1})	109	-	-
pH	3.9	-	-

*DOMD - digestible organic matter in the dry matter.

Table 4.2 Animal performance

	Treatment		
	MDG	**S**	**SED**
Dry matter intake (kg d^{-1})			
concentrate	-	2.5	
silage	-	3.4	
MDG mix	6.3	-	
total	6.3	5.9	
Liveweight gain (kg d^{-1})	1.56	1.35	0.0671*
Days to slaughter (d)	378	396	16.90*
Price (£ kg^{-1})	0.97^{a}	0.97^{a}	0.0327
Weight loss between farm and market (kg)	25.2^{a}	21.9^{a}	2.43

Values not sharing the same superscripts differ significantly (P <0.05)

Figure 4.1

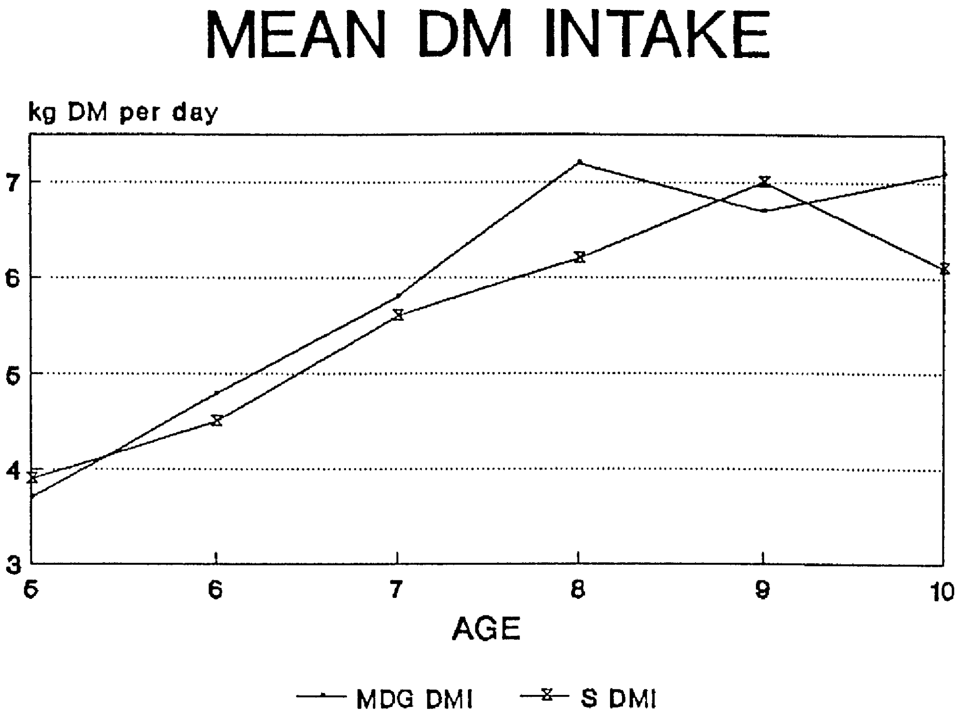


Figure 4.2

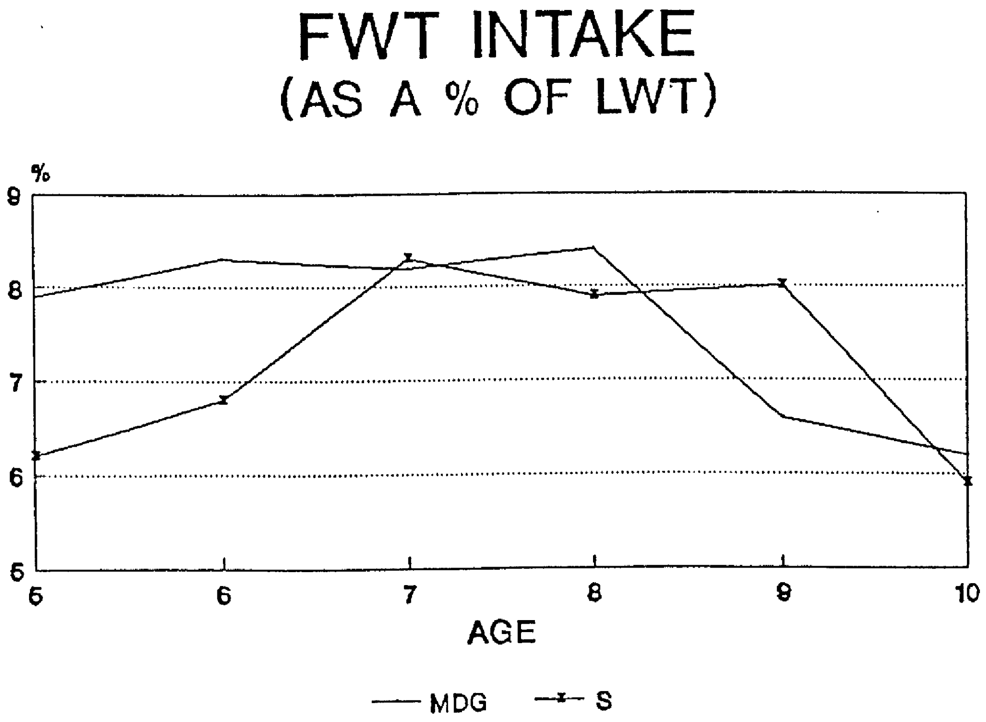
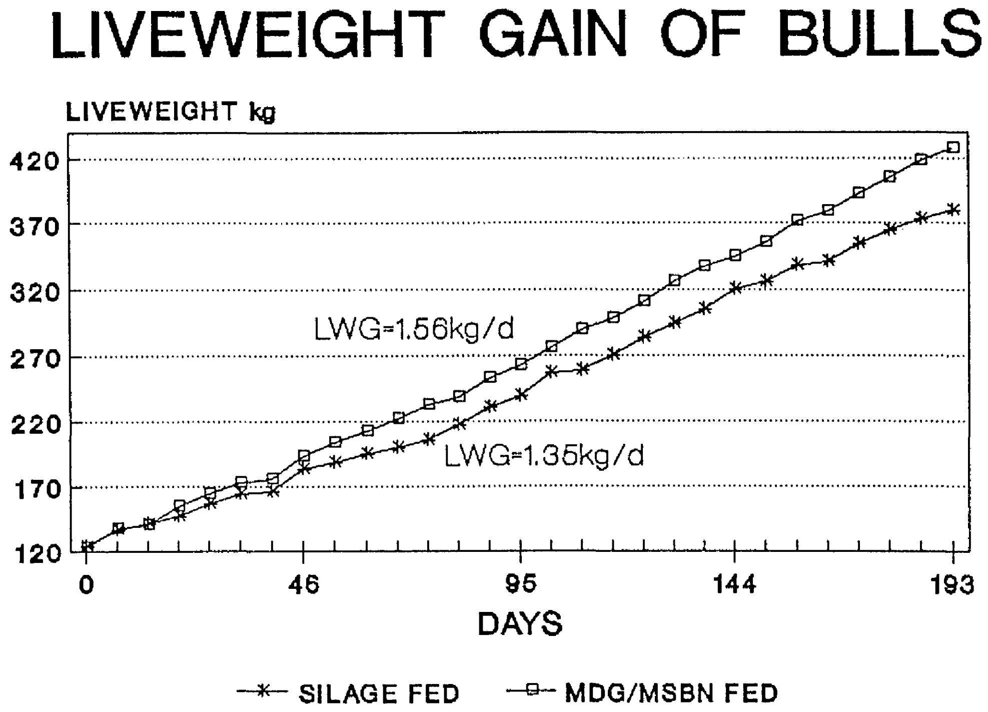


Figure 4.3



NB:
Mean liveweight gain of bulls up until the first bull was slaughtered.

Discussion

MDG mix as the sole dietary constituent in a bull beef finishing regime.

The profitability of beef production has been low for the past few years and there presently seems to be little prospect of any great improvement. Margins have been forced down by several pressures such as the reduction in financial support from the EEC, and it is likely in the future that even less support will be given from the EEC allowing prices to find their natural market levels. The loss of growth promoting implants in December 1986 had a considerable effect on beef margins, as steers could no longer give the increased performance levels achieved by the use of exogenous hormones.

In the UK, 60% of the calves reared for beef production are produced by the dairy herd and the sire selection of these calves is based predominantly on the criteria of milk production. Such calves are of the breed Friesian/Holstein and their conformation in relation to beef production is not a prime consideration. The MLC's recording and management control scheme Beefplan, from its financial data, suggested that intensive systems like cereal beef and grass silage beef were most likely to expand as they were both financially and biologically efficient and allowed good management control (MLC, 1987). Friesian/Holstein cattle have been shown to be suited to these systems of production as the high level of liveweight gain results in an acceptable carcase (Spedding, 1988).

Experiment 3 assessed an intensive system of beef production whereby Friesian/Holstein bulls were finished on a diet consisting solely of MDG mix. This system was compared to a conventional finishing system in which the cattle were fed a homemixed concentrate and silage ad-libitum. This comparison was thought to be more appropriate than a MDG mix versus barley comparison, as a farmer already rearing beef cattle on a silage/concentrate system could convert to a MDG system without additional conversion costs. Both systems require similar building and feeding facilities, and the study highlighted the effects of a land-based versus a purchased feed system.

DM intake

The trend of increased DM intake on MDG mix treatments shown in experiment 2 was repeated in experiment 3. Bulls fed MDG mix consumed 0.4 kgDM d^{-1} greater than bulls fed the silage/concentrate diet (see Table 4.2). The DM intake results for bulls on treatment MDG of 6.3 kgDM was comparable with the DM intake results reported by Firkins, Berger and Fahey (1985) for cross bred steers fed diets containing either 0. 0.25 or 0.50 of the DM as wet distillers grains (WDG). The intakes for these treatments were 6.99, 7.43 and 7.02 kgDM respectively and as the steers weighed 310 kg at the start of the experiment the DM intake would be expected to be greater. Hyslop et al (1989a) compared the DM intake of Friesian steers fed diets of MDG and MDG/MSBN. These young calves consumed 4.12 kgDM of MDG and 4.66 kgDM of MDG/MSBN, so a trend of increased DM intake when feeding MDG/MSBN compared to MDG on their own was dominant.

The mineral supplementation of the MDG treatment was satisfactory at the level of 0.05 at the MDG/MSBN DM and no depression in intake was experienced. The fact that the MDG mix was fed ad–libitum may have contributed to a smaller effect of dietary lipid on rumen function. The increased DM intake of the MDG diet compared to the silage/concentrate diet could be explained by factors such as forage particle size, rumen regulatory mechanisms, diet DM and feed composition already discussed at length in chapters 2 and 3.

Animal performance

The level of animal performance achieved on both treatments in experiment 4 was extremely high (see Table 4.2 and Figure 4.3). A liveweight gain of 1.35 kg d^{-1} on treatment S was higher than the gain of 1.2 kg d^{-1} reported by Bax (1987) for bulls on a similar diet. This high level of performance may have been due to the good quality silage fed (see Table 4.1) which had an ME of 11.0 MJ and a D–value of 75.6. Firkins et al (1985) claimed that wet distillers grains could be fed at levels of at least 50% of diet DM and performance was maintained comparable with that of steers fed corn–based finishing diets. In experiment 4, the MDG mix diet consisted of 55% MDG and the bulls had a mean liveweight gain of 1.56 kg d^{-1} which is 0.40

kg d^{-1} greater than the average liveweight gain from barley bull beef systems (MLC, 1988).

The feed conversion ratios were 3.9:1 and 4.2:1 for treatments MDG and S respectively, showing improved feed utilisation on the MDG diet. The energy needed to produce 1 kg of liveweight gain was 44 MJ for treatment MDG and 51 MJ on the silage/concentrate diet. To further examine energy utilisation k_f was calculated on a group basis for both treatments (see Table 4.3). The observed k_f value for treatment MDG was higher than that of treatment S and also higher than the predicted value for treatment MDG. The difference between the observed and predicted k_f values for the MDG ration may be explained by the discrepancies associated with the prediction of the ME value for MDG. Evidence exists to suggest that energy losses due to methane gas are significantly lower in MDG diets than other diets (Wainman and Dewey, 1982) and research has been completed on the effect of dietary lipid on the efficiency of energy utilisation. The high energy density of fat supplemented diets allow an increased level of energy consumption and an increased net efficiency of animal performance due to increased fat availability in the diet (Smith, 1988). Figure 4.4 shows the feed component source from which the proportions of digestible energy are derived for MDG/MSBN, the homemix concentrate fed in experiment 4 and the proprietary dairy concentrate fed in experiments 2 and 3.

The DE distribution for MDG/MSBN differs from the concentrate feeds in that a higher percentage of DE is derived from the fat component of the MDG diet. At the level of cellular metabolism, the major part of the energy derived from fat is provided by the fatty acids which are degraded via the pathway of ß-oxidation (McDonald, Edwards and Greenhalgh, 1988). This reaction results in a progressive shortening of the carbon chain by the removal of 2 carbon atoms at a time. The initial reaction in which the carbon atoms at the end of the chain are removed is the

Table 4.3 Efficiency of performance

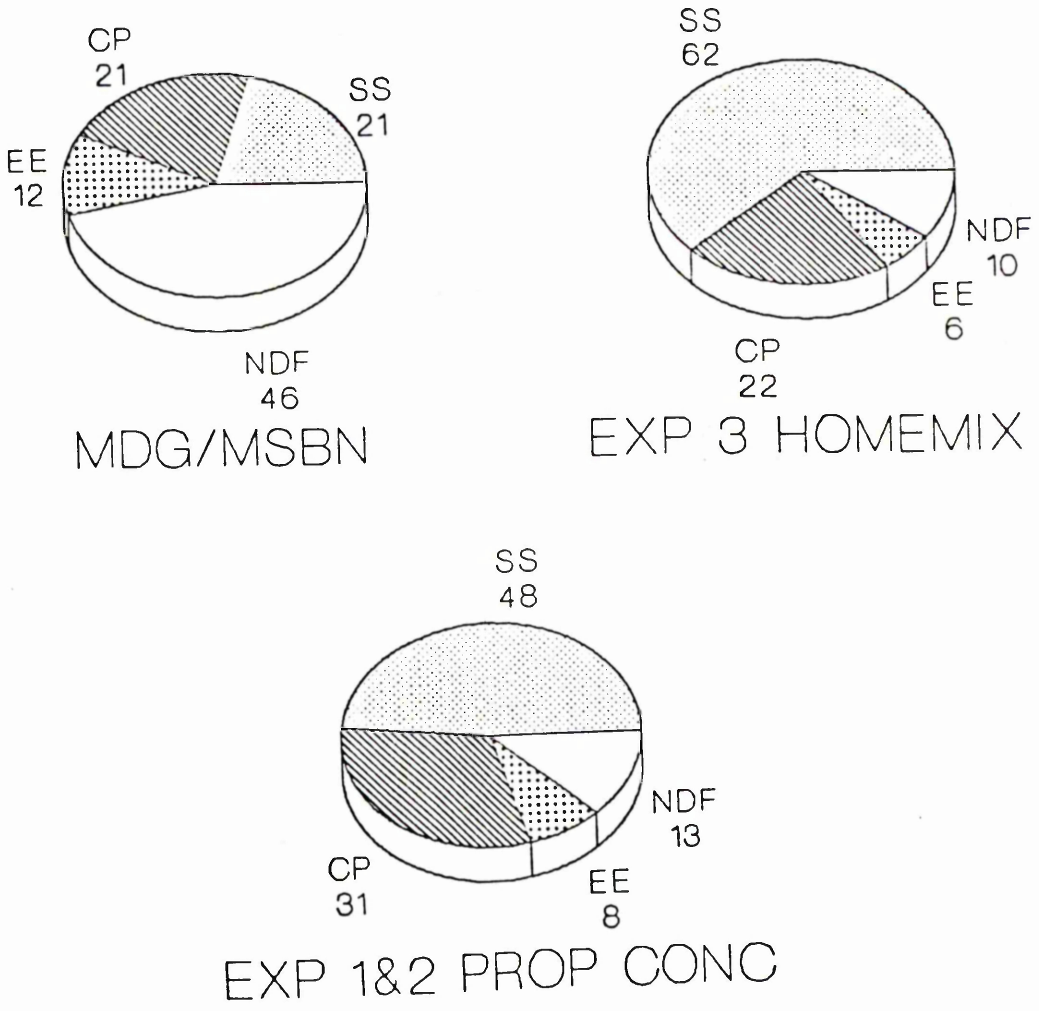
	Treatment	
	MDG	**S**
Observed liveweight gain (kg d^{-1})	1.56	1.39
Predicted liveweight gain (kg d^{-1})	1.11	1.24
Observed k_f	0.63	0.51
Predicted k_f	0.48	0.52
ME intake (MJ d^{-1})	70.50	71.10
ME maintenance (MJ d^{-1})	36.00	35.00

These results were calculated using a computer program written by Dr N W Offer (SAC, Auchincruive), which was based on the assumption that ME growth = ME intake - ME maintenance. The program incorporated ARC 80 equations for k_m and k_f. Given ME intake, total DM intake, liveweight and liveweight gain, k_f was calculated on an observed and predicted basis.

Figure 4.4

DE DISTRIBUTION

SS - starch and sugars



Note:	GE (MJ $kgDM^{-1}$)
CP	23.6
EE	39.0
NDF	18.0
SS	18.0

energy expending process and therefore since this process is only necessary once, more energy in the form of ATP is produced for the same energy expenditure by the oxidation of long rather than short chain acids. As already discussed, MDG contains lipid which consists of a high proportion of long chain fatty acids and as a result of the nature of the metabolic degradation of these fatty acids, the efficiency of energy utilisation is greater than that from short chain fatty acids or from other feed components. Table 4.4 shows the efficiency of certain nutrients as sources of energy. The increased liveweight gain shown on treatment MDG could then be explained by the increased utilisation of the energy derived from the MDG mix diet.

Table 4.4 A comparison of the efficiency of nutrients as sources of energy as ATP

Nutrient	**Mole ATP/ mole nutrient**	**Mole ATP/ 100g nutrient**	**Heat of combustion per mole ATP (kJ)**
Glucose	38	21.2 (4)	73.8 (1)
Propionic Acid	17	22.9 (3)	89.8 (5)
Acetic Acid	10	16.7 (5)	87.5 (3)
Butyric Acid	26	38.5 (2)	84.0 (4)
Aspartic Acid	16	12.2 (6)	98.0 (6)
Tripalmitin	409	50.7 (1)	78.3 (2)

Figures in parenthesis denote order of efficiency.

Source: McDonald et al (1988).

Financial performance

Gross margin data for both treatments is shown in Appendices 1 and 2. Variable costs for the MDG system amounted to £2,830 which was £145 greater than the total variable costs for treatment S. On examination of the individual variable costs the difference appears to be in the feed costs versus the forage and concentrate costs of the silage/concentrate system. The increased DM intakes on treatment MDG and the price of ensiled MDG/MSBN was higher at £124 per tonne DM than the cost of the silage. The cost of the MDG mix incorporates a charge of £21 per tonne for the mixing and ensilage of the product. This cost was based on the use of a JCB loader to mix the components and a JCB loader and 4–wheel drive tractor to ensile the material. The addition of this contract charge may seem inappropriate for management purposes however, the labour involved with the ensilaging process is worth evaluating. Homemixing is also a process which does have a considerable labour requirement and an additional charge of £26 per tonne DM would seem appropriate. The gross margin results for treatments MDG and S were £130 and £145 respectively, and so if production charges are accounted for then a silage/concentrate bull beef system is more profitable.

A factor of importance on comparison financially of the production systems is the fluctuation of the price (p kg^{-1}) paid for beef animals between September and December 1990. The average price received for bulls sold by the SAC Crichton Royal Farm was 91 p kg^{-1} in September, rising to 103 p kg^{-1} in December. Bulls fed the MDG diet finished earlier than bulls fed silage/concentrate and therefore the market price paid for these bulls in p kg^{-1} was depressed compared to prices paid later in the autumn and early winter.

The average price differential between bulls marketed in September and December was as much as £57. This variability in price should be considered when comparing the financial results for the two systems. Gross margin 3 in Appendix 1 shows financial data for both treatments excluding production charges. Both systems were profitable at the same level of return when the production charges were subtracted which farmers tend to do for management purposes.

Interest charges were the only fixed cost accounted for in the financial results, as the allocation of fixed costs to individual enterprises and indeed to such small enterprises is very difficult. Although the MDG fed bulls finished on average 3 weeks earlier than the silage/concentrate fed bulls, the interest charges were still £102 greater on treatment MDG as a result of the higher intakes and higher total feed costs. Finally, the gross margins excluding production costs amounted to £163 and £162 per bull for treatments MDG and S respectively. These levels of return may seem high as presently beef production is not particularly profitable, however the impact of the two discussed beef production systems on whole farm fixed costs such as rent of buildings, silo and land should be considered in relation to the individual farmers' situation. Table 4.5 shows the cost of feed expressed per kg of liveweight gain and if production costs are included, then the profitability of the systems are similar. In situations where the farmer has limited capacity for silage production due to the acreage or topography of the farmland, or perhaps due to the standard of the silage pits and the provision for effluent, then an MDG mix system may be implemented successfully giving acceptable levels of animal and financial performance.

Table 4.5 Feed costs

	(p)	
Cost per kg Liveweight Gain	MDG	S
excluding production charges	40	44
including production charges	49	49

CHAPTER 5 - GENERAL DISCUSSION

Experiments and future research

Changes due to economic pressures and the growth of agricultural enterprises have brought about the need for simple, effective feeding systems. The organisation of these feeding systems would primarily consider the high cost of proprietary concentrates and the costs associated with the construction and maintenance of acceptable storage.

Experiment 1 in this thesis demonstrated that MDG/MSBN could replace up to 5 kgDM of proprietary concentrate while maintaining milk yield and milk protein content. The use of MDG/MSBN as a concentrate for dairy cows would enable farmers to reduce costs normally incurred by the purchase of expensive proprietary concentrate. The potential of MDG/MSBN as a feed for dairy cows was further examined in Experiment 2, when it was fed as a complement to, or a replacement for, silage. Cows fed MDG forages produced 3 kg more milk than cows fed silage alone as the forage and on the silage/MDG mix diet both milk fat and protein content were maintained. The silage/MDG mix ration also proved the most cost effective ration. Due to a reduction in the overall farm silage requirement, farmers would be able to cut silage earlier in the season when the quality is higher or use less nitrogen fertiliser to produce the required yield. The final experiment showed that MDG/MSBN could also be used in beef rations and was a suitable feedstuff to use in a bull beef finishing regime. Bull calves from the dairy herd consumed on average 6.3 kgDM per day of MDG/MSBN and the average growth rate for these bulls was 1.6 kg d^{-1}.

Low milk fat appears to be a problem associated with the performance of dairy cows fed MDG diets. In Experiments 1 and 2 there was an average reduction in milk fat content of 3.8 g kg^{-1}. There was no reduction in milk fat content in Experiment 2 on the silage/MDG mix ration and so if higher milk fat content levels are required from dairy cows fed MDG rations, it may be necessary to incorporate the MDG in complete diets along with other forages. Future milk pricing arrangements may change due to the public's increasing interest in healthy nutrition and payments for milk fat may be given less emphasis.

In the future, simple feeding systems may well be adopted and a possible area of research may be the feeding of MDG/MSBN complete diets to dairy livestock of all stages of growth and production. Future research should include a continuous design experiment, in which MDG/MSBN/minerals are fed as the sole dietary constituent, to dairy cows at all stages of lactation. If the duration of the experiment was over a whole lactation, then health and fertility could be monitored as well as dry matter intake and animal performance. The MDG/MSBN diet was evaluated using the SAC Rationing Program (see Table 5.1) and according to the program the ration should be supplemented with a source of digesible undegradable protein. The protein requirement for a dairy cow in early or mid lactation could be supplied by the addition of 0.25kg of fishmeal per cow to the suggested ration (Table 5.1). This diet may be suitable for lactating cows avoiding complicated rationing strategies and allowing ease of management and feeding. A second experiment evaluating the potential of a similar diet for dairy–youngstock or for dry cows would provide farmers with guidelines for the wider use of MDG diets. Tables 5.2 and 5.3 show suggested rations evaluated by the SAC Rationing Program. If dairy youngstock were fed a diet of MDG/MSBN/minerals supplemented with a protein source, then satisfactory growth rates would theoretically be achieved.

Table 5.1 Dairy cow ration evaluation

Diet - MDG/MSBN/Minerals

Energy Evaluation	**DMI** (kgDM d^{-1})	**Yield** (kg d^{-1})
Early Lactation	15.0	22
Mid Lactation	12.0	15

Protein Evaluation (+/- g d^{-1})

	ERDP balance	**DUP balance**
Early Lactation	453	-25
Mid Lactation	437	-37

Diet - MDG/MSBN/Minerals & 0.25kg Fishmeal

Energy Evaluation	**DMI** (kgDM d^{-1})	**Yield** (kg d^{-1})
Early Lactation	15.5	23.0
Mid Lactation	12.5	16.0

Protein Evaluation (+/- g d^{-1})

	ERDP balance	**DUP balance**
Early Lactation	466	64
Mid Lactation	457	45

Table 5.2 Dairy Youngstock Ration Evaluation

Animal Data	110kg heifer calf medium breed size
Diet	5.5kg MDG/MSBN/Minerals +1kg Soya
Predicted Liveweight Gain	0.63 kg d^{-1}
Daily Protein Balance	DUP = + 78 g d^{-1} ERDP = +202 g d^{-1}

Table 5.3 Dry Cow Ration Evaluation

Diet 25kg MDG/MSBN/Minerals +6kg Straw

Protein Evaluation (g d^{-1})

	DMI	**ERDP**		**DUP**	
	kg d^{-1}	Req.	Supp.	Req.	Supp.
Dry Cows	12.7	982	952	-	256

ERDP Balance	-30 g d^{-1}
Urea Supplement	13 g d^{-1}

When feeding dry cows MDG diets, it may be necessary to restrict the feeding level as due to the physiological state of the cows, mineral mixes as discussed in Chapter 2 cannot be used because of the high calcium content. Milk fever, a metabolic disorder associated with hypocalcaemia, may be caused by feeding diets high in calcium during the dry period. An experimental diet for dry cows could include MDG/MSBN up to 25 kg providing the mineral supplement is a conventional supplement and not the supplement used in Experiments 1, 2 and 3.

It is very important when using rationing programs, such as the SAC package, to realise that standard figures are assumed for the chemical composition of the feeds comprising the ration. There are large differences in the cereal components of distillery by-products. Also, each distillery adopts its own techniques within the general processes outlined in chapter 1. For example, differences in drying temperature during the distilling process may result in a reduction in the degradability of the crude protein fraction of the by-product. A ration evaluation program assuming a standard figure of 0.8 for the degradability of MDG, may predict higher levels of performance than achievable if the MDG had a degradability of 0.6 due to a high temperature reaction during processing. The supply of energy and rumen degradable protein (RDP) would not be balanced and therefore performance would be affected.

Distillers use different proportions of cereals for whisky production and this too causes variation in the chemical composition of by-products. Maize distillers grains have a higher EE content than distillers grains of wheat or barley origin. This oil may be utilised with increased efficiency compared to starch as an energy source, but on the contrary diets high in oil could adversely affect performance by depressing microbial activity in the rumen.

In conclusion, distillery by-products vary greatly in chemical composition and nutritive value between distilleries and even between different batches from the same distillery. If diets including MDG are to be formulated by means of a rationing program, standard figures for feed composition should be replaced by analysed results where possible, or the results should be interpreted with caution. As already discussed in vitro prediction of the ME content of MDG is inaccurate, and in vivo analysis techniques are essential for accurate rationing.

Whole farm system

With data on the feasibility of MDG/MSBN as the sole feed for dairy cows and as a youngstock or dry cow feed, it may be possible to develop a whole farm system based on MDG/MSBN.

Dairy farming in Israel provides an interesting example of an agricultural enterprise which although it suffers several constraints, is successful due to simple feeding systems and a high level of management. No grazing is available on most Israeli farms, dairy cattle are housed all year round and feeding is completely controlled. It is common practise in Israel to feed complete diets (Amir and Kroll, 1979) and often the same diet is fed to all lactating cows. Due to the nature of the diet, feeds such as by-products can be easily utilised when they are readily available. Feed centres are responsible for the feeding operation. Individual farmers are not involved in silage-making or mixing of diets. The local feed co-operative harvests the farmers' crops, stores the crops at one site and delivers the feed mixes daily to the local farmers. The co-operatives have the advantage of buying power, to get the best deals for purchasing concentrates. Expenses incurred from machinery for harvesting and feeding and the maintenance of storage facilities are from only one site and not from many individual farms. Fewer silos are needed and therefore the risk of pollution is reduced. The Israeli system for rearing heifer replacements is a very low cost system. Heifers are fed on wastes and by-products from the age of 5 months and growth rates are sufficient for calving at 2 years old due to the absence of an uncontrolled grazing period.

In future years, British farmers may find the recently conventional feeding systems replaced by new regimes incorporating some of the policies now in use in Israel. During the 1840's dairy farms existed in most large towns (Orwin and Whetham, 1971). Dairy farms situated in Glasgow and Edinburgh provided a regular supply of milk for the liquid market by spreading the calving pattern evenly throughout the year. These cattle were fed brewer's grains from nearby malsters and their milk was retailed fresh in the early morning. In the future, we may consider improved versions of the simple feeding policies as were used 150 years ago. A whole farm MDG/MSBN system would have no land requirement for grazing or for crop production. The integration of such units with a local co-operative could result in feeding being a co-operative managed operation. Slurry disposal could be carried out by the co-operative and, perhaps utilised by arable farms.

The proposed whole farm system is obviously an extreme 'unorthodox' farming strategy but in years to come may be more readily considered. The MDG/MSBN requirement for a dairy enterprise consisting of 100 cows, 40 dairy youngstock and 48 dairy bull beef cattle amounts to 1880 tonnes (FW). The storage requirement for such a volume of forage would be 2260m^3, which could be managed efficiently and effectively by a feeding co-operative. Maintenance costs for a suitable storage pit would be minimised due to the absence of effluent and the co-operative body may be capable of resolving the farmer problems of availability.

As discussed in Chapter 1, approximately 200,500 tonnes of wet MDG are sold in Scotland each year. This tonnage could provide 133 farms with enough MDG to feed a 100-cow dairy herd on the proposed feeding system. This represents 6% of the dairy farms in Scotland, however other suitable by-products such as brewers grains are also available, and it is likely that the proposed system would be viable for a relatively small percentage of the total dairy farms in Scotland.

Such a system would seem especially attractive if situated next to a distillery or brewery plant, as were historical production units. Considering the transport costs represent approximately 15% and more of the cost of a ton of MDG, if feed costs could be reduced further then farming units in the vicinity of the distillery would be financially attractive.

MDG/MSBN has proved to be a flexible feed for cattle in present day feeding systems and with further research may lend itself to the evolved livestock feeding regimes of the future.

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APPENDIX 1

Gross Margin - MDG/MSBN Fed Bulls

Output	**£/10 bulls**	**£/bull**
476.5 kg x 96.6 p/kg	4511.00	
Special beef premium	320.00	
- calf price	700.00	
Gross output	4131.00	

Variable Costs		
Feed costs	1970.00	
Rearing to 4 months	700.00	
Bedding	40.00	
Vet/med	60.00	
Haulage	60.00	
Total	2830.00	
Gross margin	1301.00	130.00
Interest	615.00	
Gross margin - interest	686.00	68.60

Gross Margin - Silage/Conc. fed Bulls

Output	**£/10 bulls**	**£/bull**
475 kg at 96.9 p/kg	4511.00	
Special beef premium	320.00	
- calf price	700.00	
Gross output	4131.00	

Variable Costs		
Forage costs	619.00	
Concentrate costs	1207.00	
Rearing to 4 months	700.00	
Bedding	40.00	
Vet/med	60.00	
Haulage	60.00	
Total	2685.00	
Gross margin	1446.00	144.60
Gross margin per forage ha	1446.00	
Interest	454.00	
Gross margin - interest	992.00	99.20

Gross Margin Data

(Costs for homemixing and ensilage not accounted for)

Output	**£/10 bulls**
475 kg at 96.9 p/kg	4511.00
Special beef premium	320.00
- calf price	700.00
Gross output	4131.00

Variable Costs	**Silage**	**MDG**
Forage costs	619.00	1640.00
Concentrate costs	1029.00	
Rearing to 4 months	700.00	700.00
Bedding	40.00	40.00
Vet/med	60.00	60.00
Haulage	60.00	60.00
Total	2508.00	2500.00
Gross margin	1623.00	1631.00
Interest	450.00	542.00
Gross margin - interest	1173.00	1089.00
GM/bull	162.00	163.00
GM - interest/bull	117.00	109.00

APPENDIX 2

Physical Data **Silage/Conc. Treatment**

Mortality - 2%

Forage Costs: During trial period 930 kg DM per head consumed at £68/t DM.

Concentrate Costs: During trial period 700 kg DM per head consumed at £176/t DM.

This cost for concentrate is derived from £150/t DM feed cost plus £26/t DM home-mixing cost.

Interest Charges: Rate - 16% p.a.
Interest charges on calf price
on variable costs - forage costs /2
on forage fertiliser costs for 2 years
on remaining forage costs for 18 months

Physical Data **MDG/MSBN Treatment**

Mortality - 2%

Feed Costs: During trial period 1625 kg DM draff/MSBN/minerals consumed at £124/t DM.

This cost for draff/MSBN/minerals is derived from £103/t DM feed cost plus £21/t DM charge for labour at ensilage.

Interest Charges: Rate - 16% p.a.
Interest charges on calf price
on variable costs - feed cost /2
on the cost of the draff/MSBN for 18 months

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