USING RESEARCH TO REDUCE THE COSTS OF PRODUCING BEEF AND LAMB

Review of research for AgriSearch
September 2004

AgriSearch
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This review of research on beef and lamb production has been written by **Dr. Raymond Steen**

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AgriSearch was formed in 1997 to provide a mechanism through which dairy, beef and sheep farmers could have a direct involvement in near market research. Funds contributed to AgriSearch are used to commission research into the improvement and development of sheep, beef and dairy farming and to disseminate and publish the results. Beef projects are recommended to the AgriSearch Council by a Beef Advisory Group comprised of five people, of which two are farmers. Sheep projects are recommended to the AgriSearch Council by a Sheep Advisory Group comprised of five people, of which three are farmers. The AgriSearch Council is comprised of ten people of which six are farmers.

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FOREWORD

Low beef prices over the past seven years have resulted in low profit margins in beef production compared to profitability in earlier years. The proposed enlargement of the European Union and the liberalisation of world trade are likely to maintain a downward pressure on beef and lamb prices over the next few years. Combined with this, if total decoupling of direct subsidy payments for beef cattle and sheep is implemented in Northern Ireland over the next few years, this will effectively remove subsidy payments for beef and lamb production. On many beef and sheep farms, the total net profit made from producing beef and lamb over the past few years has been substantially less than the subsidies paid to beef and lamb producers. Consequently, if direct payment subsidies are totally decoupled from production in the future, the production of beef and lamb in the way that it has been produced until now would become uneconomical on many Northern Ireland farms.

Within this context, restructuring within the industry and the adoption of new approaches and methods of production will be necessary to minimise the costs of producing beef and lamb and thereby enable profitable production to continue in the future.

Research undertaken locally has played an important role in providing sound scientific and technical information which has been used to improve efficiency and reduce costs within the beef and sheep sectors. However high quality research has also been undertaken in many other countries across the world, and a considerable amount of this research is also of relevance to beef and lamb producers in Northern Ireland. Consequently AgriSearch Northern Ireland has commissioned this review of research findings which are relevant to the Northern Ireland beef and sheep industries.

There is often considerable variation in the results of individual experiments, depending on the type of cattle or sheep involved, the management of the stock, the constraints imposed within an individual experiment and the climatic conditions, including the variation in climate from year to year within one location. Thus, the results of an individual experiment may only be relevant and applicable to a situation with the same constraints and management which were in operation within that experiment. For this reason it is vitally important that beef and lamb producers have access to research information from as wide a range of experiments as possible, to obtain a good overall picture of what is likely to be applicable in a wide range of farm situations.

Within this review, the results of over 500 experiments on beef and lamb production have been reviewed, and information from over 300 of these, which are considered to be relevant to the Northern Ireland industry, have been summarised and presented in this book. The information presented relates to a wide range of production systems, from those based almost entirely on grass right through to high-input systems based on high-concentrate diets. Consequently the information presented in this review should be applicable to a wide range of farm situations throughout Northern Ireland, although the constraints which apply within a particular farm can limit the applicability of general research findings to that individual farm. Nevertheless the information presented in this review should provide a sound technical basis on which to base decisions to help reduce the costs of producing beef and lamb on most Northern Ireland farms.

SECTION 1
BEEF PRODUCTION

CHAPTER 1

REDUCING THE COSTS OF PRODUCING SUCKLED CALVES THROUGH THE USE OF BETTER QUALITY SUCKLER COWS

The main objectives for a profitable suckler cow enterprise are to produce as near as possible to one well conformed, weaned calf of good growth potential per cow in the herd per year at lowest cost. Producing cattle for most market outlets requires the use of a good continental bull as a terminal sire. However there is still much debate about which breeds are most appropriate for use as suckler cows. The most desirable characteristics of suckler cows include good fertility, ability to calve easily, a good temperament, adequate milk yield and the potential to produce live calves with a high growth rate and good conformation.

Fertility

The fertility (or infertility) of suckler cows has a major impact on the number of calves born per year per 100 cows put to the bull or artificially mated. Indeed, the number of calves born per year/100 cows has been identified as one of the most important, if not the most important factor affecting the profitability of beef production (Osoro and Wright, 1992). Good fertility enables a compact calving pattern to be maintained which reduces the costs of feeding and managing a herd. It also reduces the number of cows culled for infertility which reduces herd replacement costs.

In a recent large-scale study involving 2,500 suckler cows on 40 commercial farms across Northern Ireland, infertility was identified as a major problem (Steen and others, 1999; Ingram, 2001). For example, in this study only 50% of cows produced a calf within 390 days of producing their last calf, while only 68% of cows produced a calf within 450 days of producing their last calf. This means that 18% of cows did not produce a calf until between 12.8 and 14.8 months after they produced their last calf, and 32% of cows either did not produce a calf until after 14.8 months from they produced their last calf, or were culled from the herd. The fact that only 50% of cows produced a calf within 12.8 months of producing their last calf represents a very major financial loss to the Northern Ireland beef industry, assuming that the situation on these farms is representative of most of the suckler herds in Northern Ireland.

Both the genetics of the cow and feeding and management of the herd can have a major effect on herd fertility. The effects of feeding and management on fertility will be discussed in the next chapter.

In terms of the genetics of the cow, hybrid vigour is probably the most important factor which affects fertility. Hybrid vigour is the term used to describe the phenomenon which results in the performance of a crossbred animal being better than the average of its two purebred parents. For example, in studies in the US, Laster and others (1976) found that hybrid vigour in crossbred cows increased pregnancy rate at the end of the breeding season by 16%, while in New Zealand, Morris and others (1993) found that it increased pregnancy rate by 12% compared to that of purebred cows. Similarly, in the large-scale study in Northern Ireland, 70% of crossbred cows produced a calf within 450 days from their last calving compared to only 49% of purebred cows.

The results of a number of large-scale experiments around the world have shown that conception rates in beef cows have been higher in crosses of early maturing type (e.g. Angus and Hereford type cows) than in the late-maturing Continental crosses when the cows have been on a low plane of nutrition (Fredeen and others, 1988; Morris and others, 1993). However, this effect was not apparent in the large-scale study in Northern Ireland or in other experiments in which the cows were on a higher plane of nutrition (Fredeen and others, 1988; Amer and others, 1992). In experiments in France, culling rates due to infertility were approximately 14% in Saler cows compared to about 28% in Limousins after four parities (D'hour and Petit, 1997).

Unfortunately the heritability of fertility has been found to be very low, and consequently it is likely to be very difficult to select cows for improved fertility within a breed or cross. Thus, as far as the genetics of beef cows are concerned, the best way to improve fertility is generally by ensuring that heifers selected as herd replacements over successive generations are cross-breds. Within self contained herds, it is vitally important that the genetics of the heifers retained as herd replacements do not become dominated by one breed.

Calving difficulty or dystocia

Calving difficulty has been reported to be a significant problem in the beef industry around the world. In addition to the extra labour costs for supervision and higher veterinary costs, difficult calvings are also linked to higher calf mortality and lower subsequent conception rates (Laster and others, 1973; Langley, 1979). A range of factors have been found to influence the incidence of calving difficulty in beef cows, including gestation length, the sex of the calf, the breed and mature weight of the sire of the calf and the breed, weight and age of the cow. However the influence of all these factors can be largely attributed to their effects on only two factors, calf birth weight and the pelvic area of the cow.

The main problem in trying to select animals with lower birth weights, and hence fewer calving difficulties, is that birth weight is closely related to growth rate, so that bigger, faster growing animals tend to have higher birth weights. Consequently, if terminal sires which produce calves with higher growth rates are used, the calves also tend to be larger at birth. Bigger cows also produce larger calves, but bigger cows also tend to have larger pelvic areas and so when all the research findings in this area are considered there has been little relationship between cow size and the incidence of difficult calvings.

However, the heritability of pelvic area in beef cows has been found to be high (Koots and others, 1994), and so for a given size of cow it should be possible to select heifers with a larger pelvic area, in situations where heifer replacements are retained from within the herd.

There is also evidence that breeds of cattle differ in terms of their pelvic area relative to their size. For example, double muscled cows have been found to have smaller pelvic areas than non-double muscled cows of the same weight (Arthur and others, 1988). Other experiments have also shown differences between breed types in terms of pelvic area at constant cow live weight, as in for example the study of Laster (1974) which involved a comparison of 14 breed types. Also in the recent study in Northern Ireland, Saler cows had a significantly lower incidence of difficult calvings than most other breeds and crosses, while Belgian Blue crosses had the greatest incidence of difficult calvings. These differences are most likely to be related to the pelvic area of the different breeds of cow.

Although the size of the calf at birth is one of the two major factors affecting the incidence of difficult calvings, and therefore in general larger calves are associated with more calving difficulties, Gregory and others (1991) found that hybrid vigour in crossbred cows increased calf birth weight by 2.4 kg, but that this increase in calf birth weight had very little effect on the incidence of difficult calvings. Thus, it would seem that crossbred cows have a larger pelvic area relative to their size than purebred cows and/or the fact that they are a more robust and vigorous animal enables them to calve a larger calf than purebred cows, without experiencing any more calving difficulties.

Hybrid vigour has also been found to have a positive effect on both calf survival and calf growth rate from birth to weaning in a number of experiments in different countries (Cundiff, 1970; Gregory and others, 1978 and 1991; Smith and others, 1976; Baker and others, 1986). **Overall the benefits of hybrid vigour have been estimated to result in 15% more weight of calf weaned for each crossbred cow put to the bull or artificially inseminated compared to purebred cows.** If crossbred cows are mated with a third breed of terminal sire, this should result in further benefits of hybrid vigour in terms of the viability and growth rate of the calf. **Consequently the total benefit of hybrid vigour in terms of the weight of calf weaned per cow put to the bull has been 20 to 25% (Cundiff, 1970; Gregory and Cundiff, 1980; Morris and others, 1993). This emphasizes the importance of using crossbred cows and calves in suckler herds.**

Temperament

The temperament of suckler cows can affect the profitability of beef production in several ways. Cows with problematic temperaments have higher labour costs for handling, create a greater risk of injury to those handling them and have been shown to be more difficult to detect in heat if being bred by AI (Burrow and others, 1988). They may also have lower conception rates if bred by AI or handled a lot around and after the time of mating. Cattle with a poor temperament may also have lower growth rates in some cases, and are more prone to stress before slaughter which is likely to result in a higher incidence of high pH, dark cutting beef (Grandin, 1980) which generally has a lower market value than cherry red beef with a lower pH.

Burrow (1997) reviewed research findings on the temperament of beef cattle and calculated that the heritability of temperament is relatively high.

Consequently it should be possible to selectively breed animals with better temperament, as cows with better temperament should produce heifers with better temperament.

Stricklin and others (1980) found that the large European breeds had poorer temperament than the traditional breeds such as Angus and Hereford and also that there were major differences in temperament between strains within the same breed. Vanderwent and others (1985) found that Limousin cattle had poorer temperament than Angus cattle, while Morris and others (1994) found that Hereford and Hereford cross Friesian cows had better temperament at calving than pure Angus, South Devon cross Angus or Hereford cross Angus cows. When handled at times other than around calving, Hereford, Hereford cross Friesian and South Devon cross cows had the best temperament, while pure Angus, Charolais cross and Simmental cross cows had poorer temperament and Chianina cross cows had the worst temperament. In the major study on Northern Ireland farms, Limousin and Blonde d'Aquitaine cross cows had poorer temperament than all the other breed crosses in the study.

Milk yield

Suckler cows affect the growth rate of their calves through their genetic potential for growth rate, and also growth rate until weaning is influenced by the milk yield of the cow. Jenkins and Ferrell (1992) and Gregory and others (1992) measured the milk yield of cows of a range of beef breeds. On average over 200 to 210 day lactations, milk yields were around 6 kg/day for Hereford cows; 7.6 kg/day for Angus; 8 kg/day for Limousin and Charolais and 10 kg/day for Simmental as shown in Table 1. Sinclair and others (1998) recorded somewhat lower yields of 6 kg/day for Charolais, 7 kg/day for Angus and 9 kg/day for Simmental cows in their first and second lactations. However these values are in line with other results as the yield of first lactation animals is generally 20 to 40% lower than that of mature cows. Under hill conditions, workers in France recorded yields of 5.5 kg/day for Limousin compared to 7.5 kg/day for Saler cows.

When suckler cows are crosses between a beef and a dairy breed, an inadequate milk supply for one calf is very rarely a problem. Indeed, too much milk for one calf may well lead to problems with mastitis in the cows, especially during the summer months. However in situations in which the aim is to breed suckler cows with little or no dairy genetics in them, it is important that heifers which are to be retained as suckler herd replacements are bred by bulls with a high estimated breeding value (EBV) for milk.

Growth potential of suckled calves

Growth rate in beef cattle has a high heritability of 0.4, and consequently genetic selection for higher growth rate has successfully increased the growth potential of beef cattle across a wide range of breeds. The effects of sire breed on the relative carcass weight per day of age for a range of breeds are summarised in Table 2. Comparisons

TABLE 1 EFFECT OF SUCKLER COW BREED ON AVERAGE MILK YIELD (KG/COW/DAY) OVER A 200 TO 210 DAY LACTATION

	SOURCE OF DATA		
COW BREED	JENKINS AND FERRELL, 1992	GREGORY AND OTHERS, 1992	AVERAGE YIELD
Hereford	5.7	6.3	6.0
Angus	6.8	8.5	7.6
Limousin	6.4	9.3	7.9
Charolais	6.8	9.6	8.2
Simmental	7.6	12.0	9.8

TABLE 2 EFFECT OF SIRE BREED ON RELATIVE CARCASS WEIGHT PER DAY OF AGE (HEREFORD = 100)

	SIRE BREED							
COMPARISON	HEREFORD	ABERDEEN ANGUS	CHAROLAIS	SIMMENTAL	LIMOUSIN	BLONDE D'AQUITAINE	BELGIAN BLUE	SOUTH DEVON
1	100	95	116	112	-			109
2	100	92	122	109	-			109
3	100	99	118	115	110			105
4	100	96	113	112	-			107
5	100	-	117	108	106			104
6	100	-	117	110	112			110
7	100	-	111	107	105	107	108	-
8	100	95	107	104	101	104	105	
9	100	93	109	107	103	108	-	105
Average of all comparisons	100	95	114	109	106	109*	110*	107
Average carcass weight relative to a 300 kg carcass for Hereford	300	285	342	327	318	324*	330*	321

Comparisons 1 and 2 were reported by Kempster and others, 1982a; comparisons 3 and 4 by Kempster and others, 1982b; comparisons 5 and 6 by Kempster and others, 1988; comparison 7 by Steen, 1991a; comparison 8 by Keane, 1993 and comparison 9 by Morris and others, 1990.Values for comparison 9 are for live weight for age as carcass data were not presented.
* These values have been adjusted for missing data.

1 to 6 were undertaken in Great Britain, comparison 7 at Hillsborough, comparison 8 at Grange Research Centre and comparison 9 in New Zealand. In each experiment all of the cattle were born to the same breed of cow, so that differences between breeds relate only to the effect of sire breed.

In the seven comparisons in the U.K., Charolais cross cattle produced 17% more carcass weight per day of age than Hereford crosses, Simmental crosses 11% more, and Limousin crosses 9% more than Herefords. On the other hand, in the studies at Grange, Charolais crosses produced only 7% more carcass weight per day of age than Hereford crosses and Simmental crosses 4% more while Limousin crosses had the same carcass weight for age as Hereford crosses. This would indicate that the Hereford cattle in the Republic of Ireland have higher growth rates than those in Great Britain, relative to the growth rates of the Continental breeds. In the studies at Hillsborough and in New Zealand, the growth rates of the Continental crosses relative to Hereford crosses were intermediate between those in Great Britain and the Republic of Ireland.

In the studies at Hillsborough and Grange which also involved Blonde d'Aquitaine and Belgian Blue crosses, carcass weights for age for Blonde and Belgian Blue crosses were similar to those for Simmental crosses. In the breed comparisons in Great Britain and New Zealand which involved Aberdeen Angus and South Devon crosses, carcass weight per day of age was 5% lower for Angus than for Hereford crosses, while for South Devon crosses it was 7% higher than for Hereford crosses.

The results of the study on commercial farms in Northern Ireland are in line with these findings in that cattle sired by Charolais bulls had the highest carcass growth rate, following by Belgian Blue, Simmental and Blonde d'Aquitaine sired cattle, while Limousin-sired cattle had the lowest growth rates of the cattle sired by bulls of the Continental breeds and Angus-sired cattle had the lowest overall growth rate.

To summarise the overall findings of these breed comparisons, Charolais cross cattle consistently produced the highest carcass weight per day of age in all nine studies. Within the context of the Northern Ireland beef industry, the results of these studies would indicate that when slaughtered at the same age, Simmental, Belgian Blue and Blonde d'Aquitaine cross cattle are likely to produce about 10 to 15 kg less carcass weight than Charolais crosses, Limousin crosses about 25 kg less, Hereford crosses about 40 kg less and Angus crosses about 50 to 60 kg less carcass weight than Charolais crosses. However, it should be emphasized that there is generally major variation in the growth rate of cattle within a breed, and so cattle bred by one bull from within a breed may perform considerably better or worse than the average breed data given above would suggest. **Within any breed the most effective method of producing cattle with a high growth potential is to use bulls with high estimated breeding values for growth.** For example, in a recent study in England, cattle sired by a Limousin bull with an EBV of 29, produced 11 kg more carcass weight than those sired by a bull with an EBV of 7, which increased gross margin by £17/head (Marsh and Pullar, 2002).

SUMMARY OF THE MAIN POINTS ON REDUCING THE COSTS OF PRODUCING SUCKLED CALVES THROUGH THE USE OF BETTER QUALITY SUCKLER COWS

1. Hybrid vigour, which is the superiority of a crossbred animal above the average of its two purebred parents, has been shown to improve the fertility of suckler cows, reduce calf mortality and increase the growth rate of suckled calves. It is therefore vitally important that suckler cows in commercial herds are true crossbreds and that one breed is not allowed to dominate the genetics of a herd.
2. There are major differences between beef breeds and between strains within breeds in the temperament of cows and in the incidence of difficult calvings.
3. The heritabilities of temperament and ease of calving in suckler cows are relatively high and so selecting animals to minimise problems with bad temperament and difficult calvings can produce a substantial improvement in these characteristics and hence in the profitability of suckled calf production.
4. There are also major differences between beef breeds in the milk yield potential of suckler cows. In situations in which the aim is to breed suckler cows with little or no dairy genetics in them, it is important that heifers which are to be retained as herd replacements are bred by bulls with a high estimated breeding value for milk.
5. The breed of terminal sire used in suckler herds has been shown to have a major effect on the growth rate of the progeny and on their carcass weight for age.
6. Within any breed, using a bull with a high estimated breeding value can increase the growth rate of the progeny. In one recent study, using a bull with an EBV of 29 rather than one with an EBV of 7, increased the carcass weight of the progeny by 11 kg and gross margin per animal by £17/head.

CHAPTER 2

BREEDING MANAGEMENT AND FEEDING SUCKLER COWS

Breeding management

In beef cows the processes of maintenance of body function and lactation are generally given priority for nutrients within the animal. Consequently nutrients are preferentially partitioned to them, and so reproduction is usually the first function to suffer when nutrition is poor (Diskin and Sreenan, 1990). The results of many experiments have shown that cows which have been underfed during pregnancy, and consequently which are in poor body condition at calving, have a longer period after calving before they come back into heat again (e.g. Wright and others, 1987; 1992a and 1992b working in Scotland and Wiltbank and others, 1962; Corah and others, 1975; Bellows and Short, 1978; Dunn and others, 1969 and Selk and others, 1988 working in the United States). Similarly, in several studies in the United States cows which had a lower condition score at calving had a lower pregnancy rate during the subsequent breeding season (Richards and others, 1986; Spitzer and others, 1995; Selk and others, 1988; Bellows and Short, 1978).

In a series of experiments in Scotland, Wright and others (1987; 1992a and 1992b) calved groups of cows with an average body condition score of around 2.4 and a range of conditions on either side of this on a scale of 1 to 5, in which a cow in condition score 1 is extremely thin and one in condition score 5 is grossly overfat, as described by Lowman and others (1976).

In these studies, for each unit decrease in body condition score at calving, the length of time after calving before the cows came back into heat again was increased by 42 to 84 days. This resulted in cows which were in poor body condition at calving being unable to maintain a calving interval of even near 365 days.

Poor body condition at calving has been shown to be particularly detrimental to the subsequent fertility of first calving cows. In studies in the United States (Spitzer and others, 1995) heifers were calved with body condition scores of 4, 5 and 6 on a scale of 1 to 9 (rather than the scale of 1 to 5 used in this country). During the subsequent breeding season only 56% of the animals which calved in condition score 4 became pregnant compared to 80% of those which calved in condition score 5 and 96% of those which calved in condition score 6, as shown in Table 3. From this and other research it has been concluded that poor body condition at calving may have an even greater influence on subsequent fertility of heifers than of mature cows and therefore achieving the optimum condition score at calving is even more critical for first calving heifers than for mature cows.

The effects of the level of feeding both before and after calving on the subsequent fertility of suckler cows has also been examined in a number of experiments undertaken in Great Britain and the United States (e.g. Wiltbank and others, 1962 and 1964; Dunn and others, 1969; Richards and others, 1986; Spitzer and others, 1995; Wright and others, 1992b;). In these experiments, a low level of feeding after calving, which resulted in further weight loss in cows which were already in poor condition at calving, was found to be very detrimental to subsequent fertility, while a high level of feeding after calving generally improved the fertility of cows which calved in poor body condition.

Richards and others (1986) found that when cows which calved in poor body condition were on a low plane of nutrition after calving resulting in a live-weight loss of 0.56 kg/day, only 68% of these cows became pregnant

TABLE 3 THE EFFECT OF BODY CONDITION AT CALVING ON THE FERTILITY OF COWS REARING THEIR FIRST CALF (SPITZER AND OTHERS, 1995)

	BODY CONDITION SCORE AT CALVING (SCALE: 1 = VERY THIN TO 9 = VERY FAT)		
	4	5	6
% of cows in heat by day 60 of the breeding season	74	90	98
% of cows pregnant by day 60 of the breeding season	56	80	96

in the subsequent breeding season compared to about 90% of cows which were in good body condition at calving or which gained weight between calving and mating as shown in Table 4. Similarly, Wiltbank and others (1962) found that when Hereford cows were underfed before calving and then lost a further 0.5 kg live weight/day after calving, only 20% of them become pregnant during the subsequent breeding season compared to about 90% of cows which calved in good body condition or which gained weight between calving and mating. Also Spitzer and others (1995) found that when first calving heifers which calved in poor body condition were fed to gain a small amount of weight between calving and mating only just over 50% of them had come into heat by the end of a two-month breeding season compared to over 90% of animals which calved in a satisfactory body condition or which were on a higher level of feeding between calving and mating.

However in most experiments, level of feeding after calving had little or no effect on the fertility of cows which calved in good body condition, unless a very low level of feeding was imposed after calving which resulted in a significant loss of weight and condition between calving and mating, in which case subsequent fertility was reduced.

Overall, from the results of experiments which have examined the effects of both body condition at calving and level of feeding after calving, it has generally been concluded that the level of feeding after calving did not have as great an effect on subsequent fertility as condition score at calving.

In summary, suckler cows should have a body condition score of 2.5 to 3.5 at calving (preferably as near to 3.0 as possible). As cows in lower body condition than this at calving are likely to have poorer subsequent fertility, it is important that cows which are in poor body condition at weaning or in mid-pregnancy are separated from the rest of the herd and fed to achieve the optimum condition score at calving. If for some reason, cows do calve in poor body condition, maintaining them on a high plane of nutrition between calving and mating, so that they have a substantial increase in weight and body condition at this stage, is likely to greatly improve subsequent fertility, but in some experiments this has not been as effective as having the cow in satisfactory condition at calving.

A significant proportion of suckler cows, especially in smaller herds, are bred by artificial insemination. Achieving high conception rates by AI is dependent on good heat detection. Diskin and Sreenan (1990) identified heat detection as being the weakest link in the reproductive management of herds bred by AI. Their research indicates that producers frequently detected only 60 to 70% of cows in heat, while 20% of cows submitted for AI were not actually in heat. They also estimated that checking cows in the morning and at night would detect 70% of cows in heat, while three further checks during the day would detect 90% of cows in heat. The use of tail painting can also be a useful aid to heat detection.

TABLE 4 THE EFFECT OF BODY CONDITION AT CALVING AND LEVEL OF FEEDING AFTER CALVING ON THE FERTILITY OF BEEF COWS

	BODY CONDITION SCORE AT CALVING SCALE: 1 = VERY THIN TO 9 = VERY FAT			
	4 OR LESS		5 OR MORE	
LEVEL OF FEEDING AFTER CALVING	HIGH*	LOW*	HIGH	LOW
% of cows in heat by day 20 of the breeding season	84	67	82	89
% of cows pregnant by day 60 of the breeding season	92	68	92	85

* Cows on the high plane of nutrition after calving gained 0.3 kg live weight/day, while those on the low plane lost 0.56 kg live weight/day from calving until 2 weeks before the breeding season.

Conception rate to AI of beef cows is also affected by a number of factors. When cows are inseminated at less than 40 days after calving, or at the first heat after calving, conception rates may be as low as 20 to 40%. Normal calving rates of around 60% to a single insemination are generally not achieved until cows are 60 or more days calved at the time of AI or mating.

Research information from the UK indicates that 3 to 5% of bulls used for natural service were completely infertile, while a further 30% were classified as unsatisfactory in terms of fertility. Obviously, if an infertile bull is not detected quickly he can completely ruin the normal calving pattern of a group or herd of cows. It is therefore important that bulls are examined by a veterinary surgeon before the breeding season, and that on farms where more than one bull is being used, bulls are rotated around groups of cows to minimise the effects of an infertile bull on the calving pattern of the herd.

Feeding management

Feeding of suckler cows should be centred around having the cows in optimum body condition at various stages during the annual production cycle, especially at calving and at mating. In general, suckler cows should calve with a body condition score as near as possible to 3, and should either maintain body condition or have a slight loss of condition post-calving to reach a condition score of 2.5 to 3.0 by mating.

If spring-calving cows lose condition after calving it is important that they have adequate grazing over the summer to ensure that they regain a condition score of 3 or more before weaning in the autumn. If condition score is above 3 in the autumn then they can be fed over the winter to lose condition and achieve a score of 3 at calving, which can reduce winter feed costs. Autumn-calving cows generally gain a lot of condition over the summer. Consequently, unless the supply of grass is restricted there is a risk that they may be too fat at calving, which has been found to increase the incidence of difficult calvings. The effect of body condition at calving on the incidence of difficult calvings in a study in Scotland is shown in Table 5. This again emphasizes the importance of having cows in a condition score around 3 at calving.

For spring-calving cows which are dry during the winter, medium quality silage (D-value 63 to 67%) offered ad libitum should be sufficient to maintain body condition. However for cows in poor body condition a higher quality silage or some concentrate supplementation may be required to achieve the optimum body condition at calving. Conversely, for cows which are in above optimum condition at the start of the winter, poorer quality silage or a restricted intake of average quality silage should be sufficient, and this can reduce the cost of winter feeding. Alternatively, the condition of dry spring-calving cows can be maintained over the winter by a diet of good quality straw offered ad libitum and supplemented with 2 kg/head daily of a high-protein concentrate.

TABLE 5 THE EFFECT OF BODY CONDITION SCORE AT CALVING ON THE INCIDENCE OF DIFFICULT CALVINGS (ALLEN, 1990). (SCALE 1 THIN TO 5 VERY FAT)

CONDITION SCORE AT CALVING	COW BREED HEREFORD X FRIESIAN	BLUE GREY
	% ASSISTED CALVINGS	
2	7	4
2.5	8	6
3	8	6
3.5	10	7
4	14	10

SUMMARY OF THE MAIN POINTS ON BREEDING MANAGEMENT AND FEEDING OF SUCKLER COWS

1. Cows in poor body condition at calving have poorer subsequent fertility. Therefore cows should have a body condition score as near as possible to 3 at calving.
2. When cows with a low condition score at calving were underfed after calving, this further reduced subsequent fertility.
3. Cows in poor body condition after weaning should be given preferential treatment during late pregnancy to ensure they reach a condition score of 3 by calving.
4. If cows are in poor condition at calving, maintaining them on a high plane of nutrition after calving so that they have a substantial increase in body condition before mating is likely to greatly improve subsequent fertility, but may not be as effective as having the cow in optimum condition at calving.
5. Cows which are overfat at calving have a greater incidence of difficult calvings.

CHAPTER 3

REDUCING THE COSTS OF PRODUCING BEEF FROM GRASS

Recent research has shown that pasture-based beef production has a more positive image with consumers in that it is considered to be more environmentally friendly and provides better animal welfare and health with less dependence on antibiotics, and hence is socially more acceptable than intensive, grain-based beef production from continuously housed cattle (Cheeke, 1999; Meyer and Mullinax, 1999; Subak, 1999).

Recent research at Hillsborough has also shown that beef from cattle finished at pasture has high contents of both omega-3 fatty acids and conjugated linoleic acid (CLA). This should improve the image of beef produced from grass as a healthy food since widespread research has shown that high intakes of omega-3 fatty acids have several beneficial effects on human health (Harris, 1989; Weber and Leaf, 1991; Kinsella and others, 1990; Grimble, 1998) while ongoing research would indicate that CLA is also likely to have several beneficial effects on health (Ha and others, 1987; Ip and others, 1991; 1995 and 1996). In a series of five experiments at Hillsborough beef from cattle which were finished at pasture contained about three times as much omega-3 fatty acids and three times as much CLA as beef produced from cattle finished on high-concentrate diets (Steen and others 2002 and 2003; Steen and Porter, 2003).

Grazed grass is also the cheapest source of feed for beef cattle in Northern Ireland. The relative costs of grazed grass, grass silage and concentrates have been calculated and are presented in Table 6.

For the purpose of calculating these costs, the following assumptions have been made:

(1) Swards used for 2-cut and 3-cut silage systems and grazed swards which were utilized efficiently and poorly were reseeded every 5, 8, 15 and 15 years respectively, and costs of reseeding are based on those given by Kilpatrick and others (2001).

(2) The 2-cut silage sward received 240 kg N; 25 kg P_2O_5 and 62 kg K_2O fertilizer/hectare, the 3-cut silage sward received 300 kg N, 25 kg P_2O_5 and 62 kg K_2O fertilizer/hectare, the efficiently grazed sward received 250 kg N, 12 kg P_2O_5 and 25 kg K_2O fertilizer/ hectare, and the poorly utilized sward received 125 kg N, 12 kg P_2O_5 and 25 kg K_2O fertilizer/ hectare. All slurry was returned to the land which was harvested for silage.

(3) Yields of grass for silage are based on yields obtained at Hillsborough over several years, while yields utilized under grazing are based on estimated yields utilized by grazing beef cattle at Hillsborough over 15 years and estimated yields utilized on commercial farms. It has often been assumed that grass yields are lower under grazing than when the grass is harvested mechanically. For example, for a calculation of the relative costs of grazed grass and silage, Keady and Anderson (2000) assumed that animals grazed only 75% of the yield produced under cutting. However widespread research has shown that grazing cattle and sheep can harvest as much grass as is harvested by machinery. For example, Orr and others (1988) recorded slightly higher yields of grass harvested by grazing sheep than by mechanical harvesting, while Steen (1978); Evans (1981) and Schils and others (1999) recorded similar yields harvested by cattle as those harvested mechanically for silage. However harvesting high yields by grazing livestock is dependant on achieving efficient utilization of the grass available.

(4) Harvesting costs per tonne of grass harvested, based on current contractor quoted prices, were 25% higher for the 3-cut system than for the 2-cut system, because even though the total weight of grass to be harvested, transported to the silo and ensiled per acre was slightly greater for the 2-cut than for the 3-cut system, the swards had to be mown three times in the 3-cut system compared to only twice for the 2- cut system.

(5) Labour for feeding cattle silage and concentrates indoors and for checking cattle at pasture is charged at £6/hour. As housed cattle fed silage and concentrates incur labour costs for feeding the cattle which cattle at pasture do not incur, while cattle at pasture require extra labour for checking the cattle compared to housed cattle, it is important that these labour charges are included in the comparison of total costs.

(6) Silage storage costs vary greatly depending on the type of silo involved. For example, costs per tonne of silage are much greater for a roofed silo with purpose-built tanks to collect effluent, than if effluent is collected in tanks which are used to collect slurry during the winter, or for an open clamp silo from which the effluent is collected in tanks which are used to collect slurry in the winter. The values used in Table 6 are around the middle of the range of costs. A cost of £1/tonne for storing concentrates has been included.

(7) Land charges of £247/ha for grazing land and £259/ha for land for cutting for silage are included in the costs. The cost of land for grazing is usually slightly lower because a lot of land is not suitable for cutting for silage, but can produce

TABLE 6 RELATIVE COSTS OF GRAZED GRASS, SILAGE AND CONCENTRATES

	GRAZED GRASS		GRASS SILAGE		CONCENTRATES
	EFFICIENTLY UTILIZED	POORLY UTILIZED	2-CUT SYSTEM	3-CUT SYSTEM	
Herbage yield (tonnes DM/ha)	–	–	12.6	12.1	
Utilized yield (tonnes DM/ha)	9.0	5.0	9.8	9.4	
D-value (%)	74	68	63	71	
ME (MJ/kg DM)	11.8	10.9	10.1	11.4	
Costs (£/ha for forage, £/ tonne for concentrates)					
Reseeding	24	24	71	45	
Fertilizer/lime/herbicide	110	62	126	151	
Fertilizer application	22	15	15	22	
Harvesting	–	–	247	296	
Polythene	–	–	5	5	
Storage	–	–	67	65	1 (1)
Fencing and topping	20	15	–	–	
Rolling	–	–	12	12	
Slurry application	–	–	29	27	
Feeding and checking cattle (labour and machinery)	30	30	85	80	8 (12)
Purchase	–	–	–	–	140 (110)
TOTAL COSTS	206	146	657	703	149 (123)
Total costs including land charge					
£247/ha	456	396	872	915	146 (123)
£74/ha	280	220	718	763	146 (123)
Costs (pence/megajoule of net energy)					
£247/ha land charge	0.97	1.73	2.45	2.14	2.96 (2.44)
£74/ha land charge	0.60	0.96	2.02	1.79	2.96 (2.44)

good yields of grass under grazing. An adjustment in the cost of land to allow for a 15% loss of production in the year of reseeding has been included. The grass harvested for silage in the 2- and 3-cut systems is assumed to represent 80% of the total production from the sward for the year, except in years when the swards were reseeded, when it was assumed to represent 94% of total production.

(8) If it is assumed that land rental values of £247-259/ha are supported by the current system of direct payment subsidies within the beef, sheep and cereal sectors, then an adjustment to land rental values will be appropriate if total decoupling of subsidy payments is introduced within the next few years. It is extremely difficult to predict the impact on stock numbers in the Province and hence on land rental values if total decoupling takes place. However to examine what the impact of a major reduction in land rental values would be, the costs of grazed grass and silage have been calculated using a land charge of £74/ha.

(9) A cost of £140/tonne is assumed for purchased concentrates, or £110/tonne if straights are purchased, although prices can vary greatly from year to year.

On the basis of these costs, inefficiently grazed grass costs about 60 to 80% more per unit of net energy utilized by cattle than efficiently utilized grass. The cost of silage per megajoule of net energy utilized by cattle is about two and a half times the cost of efficiently utilized grazed grass, while the cost of concentrates is two and a half to three times the cost of efficiently utilized grazed grass, depending on the type of concentrates which are purchased and the price. However the cost of silage is only marginally more expensive than inefficiently utilized grass while the cost of concentrates is only one and a half to one and three quarters the cost of inefficiently utilized grazed grass. Clearly much of the economic benefit for beef production of Northern Ireland being a good grass growing area, is dependent on achieving efficient utilization of grazed grass. **If a land charge of only £74/ha is assumed, based on decoupling being introduced, then on the basis of the costings in Table 6, silage would cost over three times as much as efficiently utilized grass while concentrates would cost four to five times as much as efficiently utilized grass,** assuming there would be no major change in the price of concentrates after decoupling.

However, achieving good utilization of grass under grazing and a consistently high level of animal performance from grazed grass requires greater management skill than feeding cattle on diets of silage and concentrates. Consequently there is often the tendency to substitute purchased feed in place of the management effort required to achieve effective utilization of grazed grass. However replacing a low-cost source of food based on a system of feeding cattle which requires little capital investment with a more expensive source and a system requiring higher capital investment, invariably increases the costs of beef production and reduces profitability.

Grazing management

The main objectives of grazing management are to produce high yields of grass and to manage the grass and the cattle to ensure that the cattle have adequate high quality grass to achieve a high intake and a high level of animal performance, while at the same time avoiding under-utilization of the sward and wastage of grass. These objectives are best achieved by ensuring that cattle are turned out as early in the spring as is practicable and that the correct stocking rate is used throughout the grazing season, so that the feed requirements of the cattle are closely matched to the rate of grass growth.

Early turnout in the spring

The effects of turning cattle out early in the spring on overall performance to slaughter were examined in a recent experiment at Hillsborough (Steen, 2002). Continental bullocks were turned out unto a permanent pasture either on 14 March or 2 May 2000. The intention was to turn the late-turnout group out in mid- to late-April, but a period of wet, cold weather in April delayed turnout until the beginning of May. From then until the cattle were slaughtered in August, the early- and late-turnout groups grazed the same pasture as a single group. Between the two turnout dates, the late-turnout group were given silage ad libitum and achieved a live-weight gain of 0.7 kg/day. The early- and late-turnout groups were slaughtered on the same date, and the cattle which were turned out in March produced 23 kg more carcass weight per head than those turned out late as shown in Table 7. As total feed costs were similar for the two groups, and carcass value per kg was also similar as the cattle which were turned out early were slightly fatter but also had a

TABLE 7 THE EFFECT OF TURNING CATTLE OUT TO PASTURE EARLY IN THE SPRING ON PERFORMANCE (FROM STEEN, 2002)

	GROUP	
	EARLY TURNOUT	LATE TURNOUT
Date turned out to pasture	14 March	2 May
Average slaughter date	4 August	4 August
Slaughter weight (kg)	661	634
Dressing percentage	56.0	54.8
Carcass weight (kg)	370	347
Carcass gain (kg/day) 14 March to slaughter	0.69	0.53

slightly higher conformation classification, turning the cattle out early increased profitability by approximately £35 per animal in this comparison.

Rather than producing heavier carcasses, early-turnout can be used to enable cattle to be marketed early in the autumn at the same carcass weight as cattle turned out later. This reduces the demand for grass in the autumn, when grass is often scarce, and reduces the need for concentrate feeding to finish cattle off autumn grass, and may also reduce or eliminate the need for a period of expensive feeding of silage and concentrates indoors in the late autumn.

Similar benefits of early turnout to those obtained at Hillsborough, were also obtained in an experiment at the Ministry of Agriculture Farm, Knockaloe, Isle of Man (Peck, 2000). In this case turning cattle out three weeks earlier, in late March rather than mid-April, enabled them to be marketed 4 weeks earlier in the autumn at the same carcass weight. Also in two further studies at Grange Research Centre, turning cattle out three weeks earlier in the spring increased their live weight in the following autumn by 18 kg (O'Neill, Drennan and Caffrey, 2000 and 2001).

The results of these experiments indicate that turning cattle out to pasture early in the spring is likely to offer substantial economic benefits in beef production in situations in which it is practicable to do so. This may necessitate initially grazing a proportion of the area which is harvested for silage. However the reduction in the yield of grass for first-cut silage is offset by the lower requirement for silage the following winter due to an earlier projected date for turning the cattle out in the spring.

Grazing management during the main grazing season

One of the most important objectives of grazing management is to ensure that the feed requirements of the cattle are closely matched to the rate of grass growth. In Northern Ireland the majority of beef cattle are continuously grazed (i.e. set-stocked) rather than being rotationally grazed, and consequently a series of experiments were carried out at Hillsborough over six years to examine the effects of the quantity of grass available to set-stocked, autumn-born continental-cross bull calves on their performance (Steen, 1994; Steen and Kilpatrick, 1998). The effects of offering concentrates throughout the grazing season to the animals given the different allowances of grass were also examined. Continental-cross bulls were used in these experiments because they have a very high growth potential and consequently are likely to give the best responses to additional grass or concentrates. Sward surface heights of 6.5, 8, 9, 10 and 11 cm were maintained throughout the grazing season under continuous grazing management by adjusting the area of pasture available to each group of animals.

A sward height of 6.5 cm was achieved with severe

TABLE 8 EFFECT OF MEAN SWARD HEIGHT UNDER CONTINUOUS GRAZING MANAGEMENT AND CONCENTRATE SUPPLEMENTATION ON THE LIVE-WEIGHT GAIN OF CONTINENTAL CROSS BULLS (KG/DAY)

	MEAN SWARD HEIGHT (CM)				
CONCENTRATES (KG/HEAD/DAY)	6.5	8	9	10	11
0	0.84	1.09	1.17	1.21	1.20
1.6	0.95	1.12	1.19	1.20	1.22

grazing so that even the clumps of grass around the dung pats were grazed off and the sward was grazed off almost uniformly. With a height of 9 cm the sward was reasonably well grazed down between the dung pats but the clumps of grass around the dung pats usually remained ungrazed. With a mean sward height of 11 cm, large areas of the sward were only partially grazed and some areas remained ungrazed and so there was a lot of surplus grass available. The effects of sward height and feeding 1.6 kg concentrates (16% crude protein) per head daily throughout the grazing season are shown in Table 8.

Reducing sward height from 11 to 9 cm did not affect animal live-weight gain, but a further reduction to 6.5 cm reduced live-weight gain by 0.36 kg/day or 30%. This represents a loss of 66 kg live-weight gain per animal over a six month grazing season.

At a sward height of 11 cm there was a lot of dead and decaying grass at the base of the sward which rotted away and was lost, and consequently stocking rate was lower for this treatment than for the 9 cm sward height with little improvement in individual animal performance. This substantially reduced live-weight gain per hectare. On the other hand, reducing sward height from 9 to 6.5 cm increased stocking rate by 24% but reduced live-weight gain per head by 28% so that live-weight gain per hectare was reduced slightly.

Offering 1.6 kg concentrates per head daily did not improve the performance of the animals grazing the 9, 10 or 11 cm swards, but increased the live-weight gain of those which grazed the 6.5 cm sward by 0.11 kg/day or 13%. It may seem surprising that an intake of 1.6 kg concentrates produced such a small response in the live-weight gain of animals with a restricted intake of grass (i.e. 15 kg concentrates were required to produce each extra kg of live-weight gain). However it would appear that the concentrates satisfied part of the animals' hunger and this reduced their drive to maintain their herbage intake by intensive grazing of the short swards. This in turn would have further reduced their herbage intake.

In two of the experiments, the grazing behaviour of the calves was studied over a 16 hour period on four occasions during the grazing season. In these studies the animals which grazed the short swards spent 10.5 hours grazing in each 16 hour period, while those which had an adequate supply of grass from the 10 cm swards spent only 7.5 hours grazing in each 16 hour period. This shows that cattle which are grazing short swards spend a much higher proportion of time grazing in an effort to maintain their herbage intake and satisfy their hunger.

However when the cattle which were grazing the short swards were given concentrates, they reduced the time spent grazing from 10.5 to 9 hours in each 16 hour period. This reduction in the amount of time spent grazing is likely to have resulted in a lower herbage intake and hence a relatively poor response to feeding concentrates.

In a series of experiments carried out in Scotland (Lowman and others, 1988; Swift and others, 1989) the effects of sward height on the performance of beef cattle have been similar to the effects obtained at Hillsborough. In the Scottish studies reducing sward height under continuous grazing from 10 to 7 cm reduced the live-weight gain of finishing steers and heifers by 15 to 30% over three years, with a mean reduction of 22%.

The results of the studies at Hillsborough and those in Scotland would indicate that an average sward height of 9 cm is optimal for both growing and finishing beef cattle. At this sward height, near maximum individual animal performance has been maintained while at the same time efficient utilization of the available herbage has been achieved. This latter effect has ensured that a continuous supply of high quality grass was available to the animals throughout the grazing season. Consequently, high levels of individual animal performance and high outputs of live-weight gain per hectare have been achieved without concentrate feeding.

However achieving efficient utilization of pasture and high levels of individual animal performance (i.e. grazing consistently at 9 cm throughout the season) necessitates a high standard of management input and a flexible approach to the size of the areas used for grazing and for harvesting for silage. During periods of shortage of grass, due to cold and/or wet conditions or drought, an additional area which was previously intended for silage should be brought into the grazing area to maintain the availability of grass to the stock. Conversely, during periods of unusually rapid grass growth the size of the grazing area should be curtailed by harvesting an area for silage which was previously designated for grazing.

If efficient utilization of grass and a high level of individual animal performance are to be achieved in grazing cattle, it is critical that management decisions to increase or decrease stocking rate are taken early when the height of the sward starts to increase or decrease. It is too late to take decisions when the sward is out of control in terms of having too much grass or the cattle are hungry. Also, once a decision has been taken to remove part of the area from grazing, it should be cut for silage as soon as possible, as delaying cutting until there is a higher yield of grass can result in a shortage of grass later, because the regrowth on the cut area is slower following the harvesting of a heavier crop of grass (Steen, 1996c).

Swards grazed by beef cattle on many farms in Northern Ireland are under-stocked during the early grazing season (McKervey and others, 2000). As well as wasting grass this leads to a build-up of stemmy grass of low digestibility which reduces performance later in the season (Swift and others, 1989). The results of earlier studies at Hillsborough indicate that a major improvement in the efficiency of utilizing grass and in the performance of beef cattle could be achieved on many farms by turning cattle out to pasture earlier in the spring, before there is a build-up of grass or by increasing the stocking rate used during the early grazing season when grass growth is maximum. This ensures that swards are well grazed down in June, which results in a good uniform sward and high quality grass later in the season. However when a high stocking rate is used during the early season it is important that an additional area which is designated for silage is available for grazing if grass becomes scarce due to wet and/or cold weather. This is termed a buffer grazing area and has been used very successfully both at experimental level and on farms (McLaughlan and Johnston, 2000).

While the use of a high stocking rate is necessary during the early season to achieve efficient utilization of grass, especially when cattle are turned out late and there is a high yield of grass on the pasture, it has generally been found to be more beneficial in many grazing situations, to turn cattle out early at a lower stocking rate before there is a build-up of high yields of grass on the pasture. Late turnout of cattle onto swards with high yields of grass, has necessitated the use of high stocking rates to get these high yields utilized. If this coincides with a period of wet weather, these high stocking rates can result in a lot of poaching and considerable difficulty in getting the high yields of grass utilized. On the other hand the use of lower stocking rates in combination with early turnout has been valuable in minimising these problems (Steen, 2002; Steen and Porter, 2003).

Grazing system

Continuous grazing (or set-stocking) is the grazing system which is most widely used on beef farms in Northern Ireland. This involves grazing cattle continuously on the same area for all, or at least a major part of the grazing season. Continuous grazing has advantages such as low capital costs for fencing and low operating labour costs. It also encourages dense swards which minimises poaching in wet weather and unless there is a specific problem, cattle are usually very contented which encourages a high level of performance.

Alternatively, with rotational grazing, the grazing area is divided into a number of paddocks which are grazed in sequence. For example, eight paddocks each grazed for three days to give a 24 day rotation. The major advantage of rotational grazing is that it facilitates more accurate budgeting of grass supply than continuous grazing. Surpluses or deficits in grass supply can be detected more readily with rotational grazing and it is easier to take corrective action by removing or adding paddocks to the grazing area. A well managed rotational system also has potential to produce more grass and therefore to carry more cattle than continuous grazing.

While it is more difficult to manage a continuous grazing system and to budget grass supply than with rotational grazing, well managed continuous grazing can produce high individual animal performance and high live-weight gains per hectare. For example, over a 20 year period a continuous grazing system with a buffer area available if required, consistently produced live-weight gains from April to September/October of 1.2 kg/day with young bulls (Steen 1994; Steen and Kilpatrick, 1998), 1.1 kg/day with steers (Steen and Laidlaw, 1995; Steen 2002; Steen and Porter, 2003; Steen and others, 2003; R.W.J. Steen, unpublished data) and 0.95 kg/day with heifers (Steen and others, 2003; R.W.J. Steen, unpublished data). A similar level of performance with this system has also been recorded at farm level (McLaughlan and Johnston, 2000). However poor grazing management under either continuous or rotational grazing can reduce animal performance by 50% at a cost of up to £100 per animal over the grazing season (McKervey and others, 2000).

Using grass/white clover swards to reduce the cost of producing beef

The potential role of white clover as a source of nitrogen in pasture grazed by beef cattle and its effect on live-weight gain per animal and per acre in comparison with nitrogen fertilizer has been examined in many experiments. The stock carrying capacity of grass/clover swards with a low or zero input of nitrogen fertilizer in comparison with nitrogen fertilized grass swards has varied greatly depending on the nitrogen status and overall fertility of the soil. When swards are newly established after ploughing and reseeding, the nitrogen reserves in the soil are usually depleted and so there has usually been a much greater response to fertilizer nitrogen in this situation than when well established swards have been used and a high level of soil fertility has been established.

In early studies in Great Britain, Yiakoumettis and Holmes (1972) and Horton and Holmes (1974) found that the stock carrying capacity of recently sown grass swards fertilized with 300 to 500 kg of nitrogen/hectare (120 to 200 kg/acre) was approximately 50% greater than the stock carrying capacity of grass/clover swards fertilized with 50 kg of nitrogen/hectare (20 kg/acre).

However in more recent studies at Hillsborough, Steen and Laidlaw (1995) found that the stock carrying capacity of an established grass/clover sward fertilized with 50 kg of nitrogen/hectare was 86% of that of a grass sward fertilized with 360 kg of nitrogen/hectare over four years. This finding is in close agreement with early results obtained with grass/clover swards grazed by beef cattle at Johnstown Castle Research Centre, Co Wexford and at Moorepark Research Centre, Co Cork. For example, Moloney and Murphy (1963) found that over five years, the stock carrying capacity of a grass/clover sward which received no nitrogen fertilizer was 85% of that of a grass sward which was fertilized with over 400 kg of nitrogen/hectare. Similarly, Browne (1966) found that when a grass/clover ley had been established for three years, its stock carrying capacity was over 80% of that of a grass sward fertilized with over 400 kg of nitrogen/hectare. In this case, the stock carrying capacity of the grass/clover sward fertilized with 50 kg of nitrogen/hectare was over 90% of that of the grass sward which received over 400 kg of nitrogen/hectare. In a further study at Moorepark, Browne (1967) found that the stock carrying capacity of a grass/clover permanent pasture containing 30% clover, was 85% of that of a similar grass sward fertilized with over 300 kg of nitrogen/hectare.

In a series of three experiments at Grange Research Centre, O'Riordan (1995, 1996 and 1997) found that finishing steers grazing grass/clover swards which received 50 kg of nitrogen/hectare, produced over 90% of the carcass gain/hectare which was produced by cattle grazing grass swards which received 220 kg of nitrogen/hectare. In a further study at Grange, O' Riordan and others (1998) recorded a similar carcass gain/hectare for cattle grazing grass/clover swards fertilized with 50 kg of nitrogen/hectare to that obtained from similar swards fertilized with 150 to 200 kg of nitrogen/hectare. Similarly, in a recent study at Hillsborough, a grass/clover sward which received no nitrogen fertilizer had the same stock carrying capacity as a grass sward fertilized with 170 kg of nitrogen/hectare.

Overall, the results of experiments in which responses to fertilizer nitrogen have been examined indicate that a good, well managed grass/clover sward receiving no nitrogen fertilizer can have the same stock carrying capacity and produce the same live-weight or carcass gain per hectare as a grass sward fertilized with about 150 kg of nitrogen/hectare. Alternatively a grass/clover sward fertilized with 50 kg of nitrogen/hectare can sustain a similar output to that from a grass sward fertilized with 200 kg of nitrogen/hectare and so can reduce the costs of producing beef from grass.

However despite the potential benefits of clover and the fact clover seed is often included in seeds mixtures sown on Northern Ireland farms, and also that relatively low rates of nitrogen fertilizer are used on swards grazed by beef cattle on many farms, there tends to be very little clover present in many of these swards. In practice the use of grass/clover swards for beef production has been limited by the fact that maintaining a good distribution of clover in swards requires a greater management input than applying nitrogen fertilizer to grass swards. Nevertheless the extra management effort required to establish and maintain good grass/clover swards, can enable the same amount of beef to be produced per hectare at lower cost, and with less potential damage to the environment.

Management to encourage the production of clover in swards

Application of fertilizer nitrogen to grass/clover swards reduces the clover content of the swards (e.g. Marsh, 1977; Laidlaw, 1984; Steen and Laidlaw, 1995). Consequently, if swards have a reasonable distribution of clover plants and the aim is to encourage the growth of clover, then the application of nitrogen should be restricted to a maximum of 50 kg/hectare in early spring. Soils should have a minimum pH of 6.0 and an index of 2 for phosphate and potash. Inadequate lime, phosphate and/or potash can be very detrimental to the persistence of white clover, and so having a soil analysis carried out and ensuring that lime, phosphate and potash levels are appropriate is often essential in maintaining a good grass/clover sward.

Grazing management should be designed to prevent under-grazing during the early grazing season, as this results in high yields of grass on the sward at this stage which reduces clover content (Steen and Laidlaw, 1995). Swards should be grazed down tightly during April to late June and then rested from grazing for at least three weeks in July/August. Continuous grazing of grass/clover swards with sheep throughout the grazing season has been found to severely reduce the content of clover in 7the sward (e.g. Marsh and Laidlaw, 1978; Newton and others, 1985; McAdam, 1985).

Grass/clover swards should be grazed off well in late autumn by sheep, or cattle providing poaching can be avoided. Laidlaw and Stewart (1987) found that when grass/clover swards which were grazed by cattle during the main grazing season were grazed off with sheep in November, the clover content of the swards was over three times the content in the swards which were not grazed off by sheep. Thus ensuring that swards are grazed off well in late autumn is vital in maintaining a high content of clover in grass/clover swards.

Feeding concentrates to cattle at pasture

In a series of early experiments at Grange Research Centre, finishing beef cattle at pasture were given either an adequate supply of grass or a restricted supply which was controlled by the use of a very high stocking rate (Conway, 1968). Half of the cattle grazed at each stocking rate were given concentrates throughout the grazing season from early April until late October, while the other half received no concentrates. The cattle used in these experiments were of high growth potential, as indicated by a live-weight gain at the lower stocking rate, of over 1.0 kg/day throughout the almost seven month long grazing seasons. Despite this, there was little or no response to concentrate supplementation when the animals had an adequate supply of grass. From the data it can be calculated that over 60 kg of concentrates were required to produce each extra kg of live-weight gain, and although carcass gains were not reported, concentrate supplementation had little effect on killing-out percentage, and so approximately 100 kg concentrates would have been required to produce each extra kg of carcass gain.

On the other hand, when grass supply was severely restricted, to the extent that live-weight gain was reduced by over 40% compared to the live-weight gain of the cattle with adequate grass, there was a good response to concentrate supplementation, with only 7.5 kg concentrates being required to produce each extra kg of live-weight gain. Whilst this would be an economical response to concentrate supplementation, in practice it would not be economical to have cattle grazing pastures which are so bare that their live-weight gain is reduced by over 40% compared to the live-weight gain of cattle with adequate grass.

In two further experiments at Grange, autumn-born calves which were 190 kg at the start of the grazing season, produced no response in performance when given 2 kg concentrates/head daily from turnout in April until September (Harte and Fallon, 1981 and 1982). Similarly in the series of experiments at Hillsborough (discussed earlier in this chapter) in which continental cross bulls were grazed at a range of sward heights, with or without concentrate supplementation, animals with an adequate supply of grass produced no response in live-weight or carcass gain to concentrates given from turnout in April until the end of September (Steen, 1994; Steen and Kilpatrick, 1998). This was despite the fact that continental cross bulls with a high growth potential and a live-weight gain of 1.2 kg/day at pasture were used in these experiments, and this would be expected to maximise the potential for a response to concentrates.

In summary, over a total of 11 experiments at Hillsborough and Grange, there has been very little or no response in the performance of growing or finishing beef cattle with an adequate supply of grass to concentrate supplementation over the main grazing season from early April until September or October.

More recently, two experiments have been carried out at Grange Research Centre to examine the effects of feeding concentrates only during the autumn on the performance of finishing beef cattle (French and others 1998a and 1998b). In these studies, finishing cattle were kept out at pasture until mid/late November and were then slaughtered off grass without further feeding. From late August until late November, they were given a range of grass allowances, from ad libitum to a very severely restricted supply of grass without concentrates or with 2.5 or 5 kg concentrates/head/day. Overall responses in animal performance to concentrate supplementation were very good, especially when grass was very scarce. Even when the cattle had an ad libitum supply of grass there was a good response to feeding 2.5 kg concentrates/head/day, with an extra kg of carcass gain being produced for every 11 kg of concentrates consumed by the cattle. When concentrate intake was further increased to 5 kg/head/day, an extra 21 kg of concentrates were required to produce each extra kg of carcass gain.

In Northern Ireland, finishing cattle which are intended for slaughter in mid to late November are often housed early in the autumn and fed indoors for about two months before slaughter. The results of these experiments at Grange Research Centre would suggest, that if land suitable for grazing in the late autumn and an adequate supply of grass are available, then an alternative approach with these cattle would be to keep them at grass and feed concentrates. In this situation, feeding about 3.0 kg of concentrates/head/day should give a good economic response and a satisfactory level of performance to finish most types of cattle.

SUMMARY OF THE MAIN POINTS ON REDUCING THE COSTS OF PRODUCING BEEF FROM GRASS

1. Efficiently utilized grazed grass is the cheapest source of feed for beef cattle.
2. Grass silage costs 2 to 2.5 times as much as efficiently utilized grazed grass while concentrates cost 2.5 to 3 times as much as grass.
3. Inefficient utilization of grazed grass can greatly reduce the cost benefits of grass as a cheap source of feed for beef cattle.
4. Turning cattle out to grass early in the spring has produced a substantial improvement in overall performance and profitability during the finishing period in situations in which early-turnout is practicable.
5. Turning cattle out earlier in the spring has also reduced the problems of poaching associated with using a high stocking rate to utilize the high yields of grass which can be produced before cattle are turned out late in the spring.
6. Under-stocking in the early grazing season wastes grass and leads to a build-up of stemmy grass of low digestibility which reduces performance later in the grazing season.
7. Implementing good grazing management which ensures that the feed requirements of the cattle are closely matched to the rate of grass growth can substantially improve the profitability of producing beef from grass.
8. Poor grazing management can reduce animal performance to the extent that profitability can be reduced by up to £100/animal over the grazing season.
9. The use of grass/white clover swards can reduce the cost of producing beef. The key factors in maintaining a good clover content in swards are:

   (a) Adequate lime, phosphate and potash should be applied.

   (b) The use of nitrogen fertilizer should be restricted to a maximum of 50 kg/ha (20 kg/acre) in early spring.

   (c) The swards should be kept well grazed down between April and June.

   (d) The swards should be rested from grazing for at least one three-week period between late June and early September.

   (e) The swards should be well grazed off with sheep during the late autumn/early winter.
10. There has been little or no response in the performance of beef cattle to concentrate feeding when they have had an adequate supply of grass during the main grazing season between April and September.
11. Cattle finished off grass in November have given a good economic response to concentrates during September, October and November.

CHAPTER 4

REDUCING THE COSTS OF PRODUCING BEEF FROM SILAGE-BASED DIETS

As the cost of grass silage per unit of net energy utilized by beef cattle is currently about two and a half times the cost of grazed grass, the production and utilization of silage should be used to complement the efficient use of grazed grass, if the costs of producing beef are to be minimised. Thus, in most situations the quantity of silage made should be sufficient to feed cattle only when pasture grazing is not feasible due to inadequate availability of herbage for grazing and/or ground conditions do not permit grazing. Production of silage should also be timed to remove surplus grass during periods of rapid grass growth, in a manner which ensures efficient utilization of grass by grazing cattle, while at the same time ensuring that the performance of grazing cattle is not reduced by lack of grass. The value of grass silage in, and its contribution to, diets for growing and finishing beef cattle is determined by a wide range of factors including cutting system and hence digestibility, dry matter content, fermentation quality and the quantity and type of supplementary concentrates.

Effect of the stage of growth of the grass at harvesting

Digestibility is the most important factor affecting the feeding value of grass silage for growing and finishing beef cattle (Steen, 1988a and 2000) and is determined largely by the stage of growth at which grass is harvested, although the fermentation quality of silage can also affect digestibility (Parker and Crawshaw, 1982).

The results of experiments which have examined the effects of digestibility of grass silage on the intake and performance of beef cattle, and which have included an assessment of carcass gain, were reviewed by Steen (1988a). On average over nine comparisons in which the silages were supplemented with concentrates, which constituted 20 to 37% of total dry matter intake, live-weight gain and carcass gain were increased by 37 and 28 g/day respectively per percentage unit increase in silage digestibility.

The effects of cutting date or stage of growth of the grass at harvesting on beef output per hectare and the quantity of concentrates required to sustain a given level of performance are also important determinants of the economic impact of earlier or later cutting of grass for silage.

These aspects were examined in a series of six experiments at Hillsborough (Steen, 1988a and 1988b). A 2-cut system of silage making in which perennial ryegrass swards were harvested on 10 June and 16 August was compared with a 3-cut system in which harvests were taken on 23 May, 5 July and 23 August. Total dry matter yields and silage D-values for the 2-cut and 3-cut systems were 12.6 and 12.1 tonnes/hectare and 63 and 71% respectively.

Taking the first cut on 23 May rather than on 10 June, reduced grass yield by about a third. However faster recovery after the earlier cutting resulted in more grass being produced in the second and third cuts of the 3-cut system, than in the second cut of the 2-cut system, and consequently there was little difference in the total yield of grass produced in the two systems. However the rate of sward deterioration was much slower over a number of years with the 3-cut system than with the 2-cut system. This was caused by the faster recovery of growth of the perennial ryegrass in the swards following earlier cutting in the 3-cut system, especially after the first cut. Consequently the swards used in the 2-cut system required reseeding twice as often as those used in the 3-cut system. In view of the high costs of reseeding grass swards and the loss of yield in the year of reseeding, this is an important factor which should be taken into consideration when the costs of making high quality silage are being considered, and is one which is often overlooked.

The silages were offered to 380 finishing steers (Table 9). When both silages were supplemented with 2.5 kg concentrates/head/day, those given the higher digestibility silage produced 0.22 kg/day or 41% more carcass gain than those given the lower digestibility 2-cut silage. Concentrate input with the lower D silage had to be doubled to 5.0 kg/day to sustain the level of performance which was sustained by the high D silage supplemented with 2.5 kg concentrates.

Using the high D silage with a lower input of concentrates rather than the lower D silage and a higher concentrate input reduced the number of cattle finished per hectare |of silage by 26%, but also reduced the quantity of concentrates required per hectare of silage by 5.8 tonnes or 63% for a 150-day finishing period.

TABLE 9 ANIMAL PERFORMANCE FOR 2-CUT AND 3-CUT SILAGE SYSTEMS

	SILAGE SYSTEM		
	2-CUT		3-CUT
SILAGE D-VALUE (%)	63		71
Concentrate intake (kg/day)	2.5	5.0	2.5
Silage DM intake (kg/day)	6.3	5.3	6.9
Live-weight gain (kg/day)	0.96	1.22	1.22
Carcass gain (kg/day)	0.54	0.76	0.76
Cattle finished for 150 days per hectare of silage	10.3	12.3	9.1
Carcass gain in 150 days	81	114	114
Concentrates/animal (kg)	375	750	375
Concentrates consumed by cattle finished on one hectare of silage (tonnes)	3.9	9.2	3.4

The total cost of making silage in 3-cut and 2-cut systems has been estimated to be £97 and £89/tonne of dry matter respectively (Table 6). These costs include the costs of maintaining the swards, depreciation costs on a silo and an annual land charge of £259/hectare. Concentrates are estimated to cost £110/tonne, although it is recognised that this may vary depending on the source of concentrates and from year to year. In comparisons of diets involving different proportions of forage and concentrates, the impact of cereal subsidies on cereal prices is normally included in the cost of concentrates, and so the potential of the forage area to enable forage area related subsidies on cattle to be claimed should also be included in the calculation. If this is included in the cost of silage, total feed costs for a steer finished using 2-cut silage and 5 kg concentrates would be £129 compared to £109 for 3-cut silage and 2.5 kg concentrates.

However if subsidies are totally decoupled from production, as is now proposed as part of CAP reform, and so no subsidy entitlement is included in the calculation of costs, but the land charge is reduced to £74/hectare, then total feed costs for a steer finished using 2-cut silage and 5 kg concentrates would be £141 compared to £125 for 3-cut silage and 2.5 kg concentrates. However if a more expensive source of concentrates costing £140/tonne is used, the costs of feeding a steer 2-cut silage and 5 kg concentrates would be £163 compared to £136 for 3-cut silage plus 2.5 kg of concentrates.

Despite the economic benefits of high quality silage, the increasing costs of harvesting grass for silage and possibly lower cereal prices, may result in a low yield of third cut silage in a 3-cut system being uneconomical, compared to the lower cost of grazing this grass. Consequently on many beef farms only one or two cuts of silage are taken, and the first cut represents a major proportion of the total silage made on the farm.

Consequently, a further two experiments were recently carried out at Hillsborough to evaluate diets based on high- and medium-quality silages, made entirely from first cut grass (Steen and others, 2002). The high digestibility silages were cut on 25 May and had a D-value of 74%, while the medium digestibility silages had a mean cutting date of 16 June and a D-value of 64%. The silages were offered to 210 continental cross steers. Concentrate inputs ranged from 2.2 to 9.5 kg/head/day (i.e. 20 to 80% of total dry matter intake) (Table 10). Although the

TABLE 10 EFFECTS OF SILAGE DIGESTIBILITY AND THE PROPORTION OF CONCENTRATES IN THE DIET ON THE PERFORMANCE OF CONTINENTAL STEERS (STEEN AND OTHERS, 2002)

	CONCENTRATE INTAKE (KG/DAY)			
	2.2	4.7	7.3	9.5
Approximate proportion of concentrates in diet (%)	20	40	60	80
TOTAL DM INTAKE (KG/DAY)				
High D silage	9.4	10.2	10.4	10.2
Medium D silage	8.2	9.3	10.1	10.1
LIVE-WEIGHT GAIN (KG/DAY)				
High D silage	1.01	1.09	1.04	1.12
Medium D silage	0.60	0.78	1.00	1.16
CARCASS GAIN (KG/DAY)				
High D silage	0.67	0.78	0.77	0.79
Medium D silage	0.38	0.48	0.64	0.77
CARCASS GAIN IN 120 DAYS (KG)				
High D silage	80	94	92	95
Medium D silage	46	58	77	92

highest proportion of concentrates in the diet averaged 80% over the total feeding period, these diets contained 85 to 90% concentrates over a major part of the finishing period to compensate for the initial period when concentrate intake was being gradually increased from a relatively low level.

On average over the 20% and 40% concentrate levels, responses in live-weight gain and carcass gain to increased digestibility were 36 and 30 g per percentage unit increase in digestibility, which are close to those obtained in the earlier review (Steen, 1988a).

This was equivalent to an increase of approximately 70% in carcass gain or an extra 35 kg carcass weight over a 120-day finishing period. As the proportion of concentrates in the diet was increased the importance of silage quality declined, so that at the highest input of concentrates silage quality had little effect on live-weight or carcass gains.

The high digestibility silage supplemented with 2.2 kg concentrates/day sustained a carcass gain of 0.67 kg/day. From the relationship between concentrate input and carcass gain, it can be calculated that to sustain this gain with the medium digestibility silage would require a concentrate intake of 7.8 kg/day. If these two diets are costed on the same basis as outlined above, and assuming a cost of £110/tonne for concentrates, the total feed costs for finishing each animal over a 120-day period would be £88 for the high digestibility silage supplemented with 2.2 kg concentrates/day compared to £127 for the medium digestibility silage supplemented with 7.8 kg concentrates/day, when the potential of the silage area to collect forage area related subsidies is included in the calculation. Alternatively, when no subsidy entitlement is included in the calculation and a land charge of £74/hectare is used, total cost per animal

TABLE 11 FEED COSTS FOR FINISHING A CONTINENTAL CROSS STEER FOR 150 DAYS USING HIGH OR MEDIUM DIGESTIBILITY SILAGE

	DIET	
	MEDIUM D SILAGE	HIGH D SILAGE
Silage D value	64	74
Concentrate intake (kg/head/day)	7.8	2.2
Feed costs for 150 days – assuming concentrates cost £110/tonne, a land charge of £259/ha and forage area related subsidies are claimed	£127	£88
Assuming concentrates cost £110/tonne, a land charge of £74/ha and no subsidies are available on the cattle	£133	£102
Assuming concentrates cost £140/tonne, a land charge of £259/ha and forage area related subsidies are claimed	£155	£96
Assuming concentrates cost £140/tonne, a land charge of £74/ha and no subsidies are available on the cattle	£161	£110

finished would be £102 for the diet based on high digestibility silage compared to £133 for the medium digestibility silage and higher input of concentrates as shown in Table 11.

Alternatively, if a concentrate costing £140/tonne is used the cost of finishing a steer using the high digestibility silage plus 2.2 kg of concentrates would be £96 compared to a cost of £155 for medium digestibility silage plus 7.8 kg of concentrates/head/day.

Effect of the type of sward harvested for silage

Research undertaken at Grange Research Centre, Co Meath, has shown that when swards contain little or no ryegrass, reseeding can result in marked improvements in silage yield and in silage quality (O'Kiely, 2000). This is because ryegrass has been shown to have higher yields, high digestibility and a higher sugar content than other grass species.

Two experiments were undertaken at Hillsborough to examine the effects of the date on which early- and late-heading varieties of perennial ryegrass were harvested for first-cut silage (Steen, 1992a). Swards containing either three early-heading or three late-heading varieties were harvested over a range of dates from 19 May until 13 June in each of two years. The silages were given to steers and heifers with a mean input of one kg concentrates/day. A selection of the average results for the two years are given in Table 12.

On average over the two years, the early varieties reached 50% ear-emergence on 19 May and the late varieties on 12 June. However, despite the fact that there was a difference of 24 days in the heading dates of the two swards, to sustain the same level of animal performance from the silages, the late varieties had to be cut only seven days after the early varieties. This was due to the fact that the digestibility of the late varieties started to decline rapidly well before ear-emergence, while the digestibility of the early varieties remained high until ear-emergence. Consequently, when both swards were cut at ear-emergence (i.e. 19 May for the early varieties and 12 June for the late varieties) the cattle given silage made from the late varieties gained 36% less carcass weight than those given silage made from the early varieties.

Overall the digestibility of the swards declined by 0.5 percentage units per day or 3.5 percentage units per week. The date of harvesting the first cut did not affect the digestibility of the second and third cuts after a constant regrowth interval.

TABLE 12 EFFECT OF THE DATE OF CUTTING EARLY- AND LATE-HEADING VARIETIES OF PERENNIAL RYEGRASS ON THE PERFORMANCE OF CATTLE GIVEN FIRST-CUT SILAGES

	SWARD TYPE		
CUTTING DATE	EARLY VARIETIES 19 MAY	LATE VARIETIES 26 MAY	12 JUNE
Silage d-value (%)	73	73	65
Silage intake (kg dry matter/day)	6.8	6.7	6.0
Live-weight gain (kg/day)	1.05	1.06	0.69
Carcass gain (kg/day)	0.64	0.64	0.41

The conclusions from these experiments are that in order to produce good quality silage which is capable of sustaining high levels of performance in beef cattle, lowland swards of early-heading varieties of perennial ryegrass should be cut around ear-emergence (i.e. usually around 20 May) and late-heading varieties should be cut one week later (i.e. around 27 May), which is well before ear-emergence.

Effects of wilting grass prior to ensiling

Wilting grass in the field to above a dry matter content of 25% virtually eliminates the production of silage effluent. However responses in the intake and performance of beef cattle to wilting have been extremely variable. In a few experiments, wilting has resulted in large increases in intake and live-weight gain. For example, increases in intake of 20 to 85%, and in live-weight gain of 0.12 to 0.29 kg/day have been reported (Alder and others, 1969; Forbes and Jackson, 1971; Hinks and others, 1976; Dawson and others, 1999a). However in the majority of experiments, increases in intake due to wilting have been much smaller (about 10%) and there has been little effect on live-weight gain. Furthermore in some experiments responses in carcass gain to wilting have been proportionately smaller than those in live-weight gain, due to the cattle which were given wilted silage having a lower dressing percentage than those given unwilted silage (O'Kiely and others, 1988), and when wilting has taken place during poor weather, it has reduced carcass gain in some experiments (e.g. Steen, 1984a).

Steen (1984b) reviewed the results of early experiments which examined the effects of wilting on the intake and performance of beef cattle. On average over 40 comparisons of wilted and unwilted silages, wilting increased intake by 18% and live-weight gain by 0.04 kg/day, whereas in the six comparisons for which carcass gains were reported, wilting reduced carcass gain by 0.03 kg/day (i.e. 4 kg over a 150-day winter feeding period).

Wright and others (2000) reviewed the results of a smaller number of comparisons of wilted and unwilted silages with emphasis on more recent studies, and reported an average increase of 0.07 kg/day in live-weight gain and an average reduction in carcass gain of 0.04 kg/day (i.e. 6 kg over a 150-day winter feeding period).

Wright and others (2000) also undertook a detailed analysis of the factors which affect the response in animal performance to wilting. From their analysis, they concluded that the rate of drying in the field and the proportion of concentrates in the diet were the two most important factors affecting the response in animal performance to wilting. A faster rate of drying in the field produced a greater positive response in animal performance to wilting, while the response to wilting declined as the proportion of concentrates in the diet increased. The response in intake to wilting was also greater when the unwilted silage was poorly preserved. Significant benefits in the performance of beef cattle as a result of wilting are likely to be achieved only when a rapid rate of drying is achieved in the field. As the rate of drying in the field has been shown to be very closely related to the weight of mown crop per unit area of ground (Wright, 1997), spreading the grass during or after mowing should greatly improve the speed of wilting and hence maximise animal performance from wilted silage.

Despite the fact that the effects of wilting on animal performance have been variable, it is important to consider that the benefits of wilting, other than its effect on animal performance, may well justify its use. For example, achieving a significant increase in the dry matter content of grass through wilting reduces the volume of effluent produced and hence the risk of pollution of waterways which is of paramount importance in any silage-making system. Wilting also reduces the weight of material to be chopped and transported to the silo per tonne of dry matter ensiled. These benefits alone may justify wilting, but if a positive response in animal performance can also be achieved through rapid drying in the field over a short period, this can contribute to a reduction in the costs of producing beef.

Use of additives in silage making

Many experiments have been undertaken to evaluate silage additives. Formic acid has generally been found to be the most effective additive for improving silage fermentation and the performance of beef cattle given silage made under difficult conditions so that the untreated silage was poorly preserved. For example, in five comparisons of untreated and formic acid-treated silages in which the untreated silages were not well preserved (i.e. ammonia N content greater than 10% of total N), formic acid treatment increased carcass gain by 94 g/day or 22% (O'Kiely and Flynn, 1987; Kennedy, 1990a; Carson and Kennedy, 1991; Keady and Steen, 1994 and 1995). However in a further 11 comparisons in which the untreated silages were well preserved (ammonia-N content less than 10% of total N), formic acid increased carcass gain by only 30 g/day or 6% (Steen, 1985a; Kennedy and others, 1989; Kennedy, 1990a and 1990b) as shown in Table 13.

Responses in the performance of beef cattle to the use of bacterial inoculants as silage additives have also been variable (Kennedy and others, 1989). In 11 comparisons which have included an assessment of carcass gain, treatment of grass with an effective bacterial inoculant prior to ensiling increased carcass gain by 40 g/day or 9% (Kennedy and others, 1989; Keady and Steen, 1994 and 1995; O'Kiely, 1996; R.W.J. Steen, unpublished data). The magnitude of the responses to inoculant treatment has been fairly consistent across a wide range of ensiling conditions.

Sulphuric acid-based additives

Sulphuric acid has been used as a cheaper alternative of formic acid as a silage additive, and has resulted in an improvement in silage fermentation in some experiments. On average over eight experiments in which the carcass weight of beef cattle has been recorded, cattle given silages treated with sulphuric acid have produced 3% less carcass weight gain than cattle given silages made with

TABLE 13 THE EFFECT OF SILAGE ADDITIVES ON THE PERFORMANCE OF BEEF CATTLE

ADDITIVE	EFFECT OF ADDITIVE ON CARCASS GAIN
Formic acid (when untreated silages were poorly preserved) (Average of 5 comparisons)	Increased carcass gain by 0.09 kg/day (i.e. 14 kg in 150 days)
Formic acid (when untreated silages were well preserved) (Average of 11 comparisons)	Increased carcass gain by 0.03 kg/day (i.e. 5 kg in 150 days)
Bacterial inoculants (Average of 11 comparisons)	Increased carcass gain by 0.04 kg/day (i.e. 6 kg in 150 days)
Sulphuric acid (Average of 8 comparisons)	Carcass gain was 3% lower

no additive (O'Kiely and Poole, 1989; Kennedy, 1990a; O'Kiely, 1996). On the basis of these results, sulphuric acid could not be regarded as being appropriate for use as a silage additive for beef production.

Molasses

The results of experiments which have examined the value of molasses as an additive were reviewed by Keady (1996). On average over nine comparisons the use of molasses at rates of 9 to 30 litres/tonne of grass increased the live-weight or carcass gain of beef cattle by 6%. However it should be noted that in most of these comparisons, the untreated silage was poorly preserved, and consequently the use of formic acid increased live-weight or carcass gain by 20%. Thus the response to molasses was less than one third of the response to formic acid, despite the relatively high rates of application of the molasses.

Economic effects of applying an additive

When considering the potential economic benefits of applying a silage additive it is important to ensure, not only that the additive has been shown to be an effective additive in terms of having given positive responses in animal performance in independent experiments, but also that the use of the additive is the most cost effective method of obtaining the response or increase in animal performance. For example, the cost of applying a silage additive should be compared with the cost of feeding additional concentrates to achieve the same response in growth rate as that obtained from applying the additive.

Furthermore, evaluations of silage additives in beef cattle rations have generally involved zero to modest inputs of concentrates which tends to maximise the response to the additive, while in practice, beef cattle rations generally contain a higher proportion of concentrates. Dawson and others (1998) examined the relative effects of treating grass with an effective additive prior to ensiling or increasing the digestibility of silage by harvesting grass at an earlier stage of growth on the digestible energy intake of beef cattle, offered silages either as the sole feed or as part of a diet which contained approximately 45% concentrates on a dry matter basis. When the silages were supplemented with concentrates the response in energy intake to additive treatment was only 30% of the response obtained when no concentrates were fed, while the response to higher digestibility when the silages were supplemented with concentrates was 70% of the response obtained when no concentrates were fed.

Furthermore, Agnew and Carson (2000) offered beef cattle silages which were made without or with an additive, either without concentrate supplementation or supplemented with 4.5 kg of concentrates/head/day. **When the cattle were given 3.0 or 4.5 kg of concentrates/head/day the response in carcass gain to treatment of the silage with an additive was only 6% (i.e. less than one tenth) of the response which was obtained when no concentrates were fed.**

Thus, responses to silage additives are likely to be much lower when the silages are supplemented with appreciable quantities of concentrates than when no concentrates are fed, and so this effect should also be taken into consideration when the relative economics of using a silage additive or feeding extra concentrates to achieve a given level of animal performance are being considered. When this effect is taken into consideration, the use of many silage additives for silage offered to beef cattle is unlikely to be as cost effective as feeding additional concentrates at a cost of £110/tonne or less, to achieve the same level of performance, except when grass is ensiled under very difficult conditions.

SUMMARY OF THE MAIN POINTS ON REDUCING THE COSTS OF PRODUCING BEEF FROM SILAGE-BASED DIETS

1. Digestibility is the most important factor affecting the feeding value of grass silage.
2. Increasing the digestibility of grass silage can substantially reduce the costs of producing finished cattle, but this is dependent on the resources available on individual farms.
3. Rapid wilting of grass for a few hours before ensiling can improve the performance of beef cattle, but prolonged wilting in difficult weather has substantially reduced the performance of finishing cattle.
4. Applying formic acid or a bacterial inoculant to grass silage can improve the performance of beef cattle.
5. However feeding more concentrates instead of using an additive may produce a similar response in animal performance at a lower cost.

CHAPTER 5

ALTERNATIVE FORAGES FOR BEEF CATTLE

Maize Silage

The effect of replacing either part, or all of the grass silage in the diet of beef cattle with maize silage on the performance of the cattle depends on the quality of both the grass and maize silages.

While the quality of grass silage declines as the crop matures, as discussed in the previous chapter, the feeding value of maize silage has been found to increase as the crop matures up to a dry matter content of 30 to 35% and up to a starch content of about 30%. For example, Lordan and Keane (1999) found that the live-weight gain of cattle given maize silage with a dry matter content of 35% and a starch content of 37% was 20% higher than the live-weight gain of cattle given silage with a dry matter content of 21% and a starch content of 10%. Similarly, in another experiment at University College Dublin, O'Gorman and others (1998) found that the carcass gain of cattle given maize silage with dry matter and starch contents of 34 and 27% was 13% higher than the carcass gain of cattle given silage with dry matter and starch contents of 23 and 9% respectively.

In an experiment at Grange, O'Kiely and Moloney (2000) compared good quality grass silage with three good quality maize silages. The grass silage had a D-value of approximately 70% while the three maize silages used in the comparison had an average dry matter content of

TABLE 14 A COMPARISON OF GOOD QUALITY GRASS AND GOOD QUALITY MAIZE SILAGES FOR FINISHING BEEF CATTLE (O'KIELY AND MOLONEY, 2000)

	SILAGE TYPE		
	100% GRASS	50% GRASS + 50% MAIZE	100% MAIZE
Concentrate intake (kg/day)	3.0	3.0	3.0
Silage intake (kg DM/day)	5.1	6.8	6.8
Live-weight gain (kg/day)	0.85	0.95	0.98
Carcass gain (kg/day)	0.65	0.70	0.74
Feed conversion efficiency (kg feed dry matter required to produce one kg carcass gain)	12.0	13.4	13.0

TABLE 15 A COMPARISON OF GOOD QUALITY GRASS AND POOR QUALITY MAIZE SILAGES FOR FINISHING BEEF CATTLE (O'KIELY AND MOLONEY, 1995)

	SILAGE TYPE		
	100% GRASS	50% GRASS + 50% MAIZE	100% MAIZE
Concentrate intake (kg/day)	3.0	3.0	3.0
Silage intake (kg DM/day)	6.1	7.1	6.1
Live-weight gain (kg/day)	1.39	1.38	1.07
Carcass gain (kg/day)	0.87	0.79	0.63
Feed conversion efficiency (kg feed dry matter required to produce one kg carcass gain)	7.0	9.0	9.7

31% and an average starch content of 39%. The cattle were given 3 kg of concentrates/head/day. The results are summarised in Table 14 Including maize silage in the diet increased silage dry matter intake by 33%. When the cattle were given a 50/50 mixture of grass and maize silage, carcass gain was 8% higher, and when they were given 100% maize, it was 14% higher than when they were given no maize silage. However including maize silage in the diet increased the total quantity of feed required to produce one kg of carcass gain by 10%.

In a further study at Grange, O'Kiely and Moloney (1995) examined the effect of including poor quality maize silage in the diet of cattle given good quality grass silage supplemented with 3 kg of concentrates/head/day. In this experiment, the grass silage had a D-value of approximately 70%, while the maize silage had a dry matter content of 21%. As shown in Table 15, feeding a 50/50 mixture of grass and maize silages reduced carcass gain by 9%, while feeding 100% maize silage resulted in a major reduction in carcass gain of 28% compared to cattle given 100% grass silage. Again, including maize silage in the diet reduced feed efficiency in that the cattle given 100% maize silage required 38% more total feed dry matter to produce each kg of carcass gain than the cattle given 100% grass silage.

On the other hand, Browne and others (2000) working in the South of England, examined the effect of replacing below average grass silage with good quality maize s ilage in the diet of cattle which were given only 2 kg of concentrates/head/day. The grass silage had a D-value of 65%, while the maize silage had dry matter and starch contents of 33 and 30% respectively. In this case replacing below average grass silage with good quality maize silage increased carcass gain by 50% and reduced the quantity of feed required to produce each kg of carcass gain by 21% as shown in Table 16.

However in a study undertaken at University College Dublin, by O'Gorman and others (1998), and in one undertaken at Hillsborough by Kirkland and Patterson (2003), replacing either 40 or 100% of below average quality grass silage in the diet of finishing cattle by good quality maize silage, with dry matter and starch contents of around 35 and 32% respectively, produced much smaller responses in carcass gain than that obtained in the experiment in England.

In two experiments which were undertaken at University College Dublin, McCabe and others (1995) and Breen and Keane (2000) examined the effects of replacing poor quality grass silage with poor quality maize silage. The grass silages had an average D-value of around 63%, while the maize silages contained 21% dry matter and only 2% starch on average. As shown in Table 17, replacing part or all of the poor quality grass silage with poor quality maize silage improved carcass gain slightly but had little effect on feed conversion efficiency.

Thus, overall the effects of using maize silage rather than grass silage for finishing beef cattle depends greatly

TABLE 16 A COMPARISON OF BELOW AVERAGE GRASS SILAGE AND GOOD QUALITY MAIZE SILAGE (BROWNE AND OTHERS, 2000)

	SILAGE TYPE		
	100% GRASS	50% GRASS + 50% MAIZE	100% MAIZE
Concentrate intake (kg/day)	2.0	2.0	2.0
Silage intake (kg DM/day)	6.3	7.1	7.8
Live-weight gain (kg/day)	0.92	1.13	1.26
Carcass gain (kg/day)	0.58	0.76	0.87
Feed conversion efficiency (kg feed dry matter required to produce one kg carcass gain)	14.3	12.0	11.3

TABLE 17 A COMPARISON OF POOR QUALITY GRASS AND POOR QUALITY MAIZE SILAGES FOR FINISHING BEEF CATTLE(AVERAGE RESULTS OF TWO COMPARISONS)

	SILAGE TYPE		
	100% GRASS	50% GRASS + 50% MAIZE	100% MAIZE
Concentrate intake (kg/day)	3.7	3.7	3.7
Silage intake (kg DM/day)	6.1	6.7	7.3
Live-weight gain (kg/day)	0.78	0.83	0.91
Carcass gain (kg/day)	0.57	0.59	0.64
Feed conversion efficiency (kg feed dry matter required to produce one kg carcass gain)	16.5	17.0	16.4

on the quality of grass silage and the potential of an individual farm to produce good quality maize silage. This in turn is determined by several factors including geographical location, aspect (e.g. north or south facing), soil type and altitude. In situations in which arable aid payments can currently be claimed on maize, this can reduce its cost of production relative to grass silage, but only if growing maize instead of grass silage does not reduce the amount of subsidies which can be claimed on cattle on the farm because of the reduced area of forage. In any case if direct payments are decoupled within the next few years this possibility would no longer arise.

Whole-crop wheat or barley

Two experiments have been undertaken at Grange by O'Kiely and Moloney (1998 and 2002) to compare grass and whole-crop wheat silages for finishing cattle. The grass silages were of fairly good quality with an average D-value of around 70%. The whole-crop wheat was harvested either when it had a dry matter content of around 38% and was ensiled without an additive, or was left to mature until it had a dry matter content of around 50% when it was ensiled with the addition of urea as an additive. The silages were supplemented with 3 kg of concentrates/head/day. The results are summarised in Table 18. The cattle ate 16 to 18% more of the whole-crop wheat silage than of the grass silage. However feeding whole-crop wheat silage reduced live-weight gain slightly and also reduced dressing percentage, presumably due to the cattle which were given the drier, more fibrous wheat silages having more gut fill. Consequently feeding whole-crop wheat silage rather than grass silage reduced carcass gain by 6 to 13% and increased the quantity of total feed dry matter required to produce each kg of carcass gain by about 20 to 30%.

Similarly results have been obtained in two experiments at Hillsborough with whole-crop barley silage in comparison to grass silage (Steen, 1984c), except that in this case carcass gain was 23% lower for the barley silages than with good grass silages.

The results of these experiments would indicate that whole-crop wheat or barley silages do not compare well with good quality grass silage in terms of animal performance, and consequently they are unlikely to be economical to produce in comparison to grass silage, unless they can be produced at a much lower cost than grass silage. However on the basis of the costings given by Kilpatrick and others (2001), this is unlikely to be the case in Northern Ireland.

TABLE 18 A COMPARISON OF GRASS AND WHOLE-CROP WHEAT SILAGES FOR FINISHING BEEF CATTLE. (AVERAGE RESULTS OF TWO EXPERIMENTS AT GRANGE RESEARCH CENTRE)

	SILAGE TYPE		
	GRASS	WHOLE-CROP WHEAT	
	19% DM	38% DM	49% DM
Concentrate intake (kg/day)	3.0	3.0	3.0
Silage intake (kg DM/day)	4.9	5.8	5.7
Live-weight gain (kg/day)	0.96	0.94	0.88
Dressing percentage	54.3	53.2	52.6
Carcass gain (kg/day)	0.67	0.63	0.58
Feed conversion efficiency (kg feed dry matter required to produce one kg carcass gain)	11.4	13.4	14.7

SUMMARY OF THE MAIN POINTS ON THE USE OF ALTERNATIVE FORAGES FOR BEEF CATTLE

1. The effects of replacing grass silage with maize silage in the diet of beef cattle depends on the quality of the grass and maize silages.
2. Replacing poor quality grass silage with good quality maize silage has substantially increased the performance of beef cattle as shown in Table 16, while replacing good quality grass silage with poor quality maize silage has substantially reduced performance as shown in Table 15.
3. The economics of growing maize silage for beef cattle are likely to vary greatly depending on the quality of maize silage which can be grown on an individual farm, the quality of the grass silage which it replaces and the relative costs per tonne of dry matter of producing maize and grass silages on individual farms.
4. Replacing grass silage with whole-crop wheat or barley silage has reduced the performance of finishing cattle as shown in Table 18.
5. Consequently whole-crop wheat or whole-crop barley silage is unlikely to be economical to produce instead of grass silage unless it can be produced at a much lower cost than grass silage.

CHAPTER 6

REDUCING THE COSTS OF BEEF PRODUCTION THROUGH THE OPTIMUM USE OF CONCENTRATES

A number of factors influence the optimum concentrate intake of beef cattle. These include:

(1) Whether the cattle are to be finished or stored over the winter and turned out to pasture again in the spring.

(2) The growth potential of the cattle.

(3) The quality of the silage or other forage being fed.

(4) The overall economics of beef production and the availability of silage and other resources on the farm.

Concentrate inputs for young growing cattle

The results of extensive research at Hillsborough, at Grange Research Centre and in Scotland (Steen, 1986; Keane and Drennan, 1989; 1992a and 1992b; Lowman and others, 1996) would indicate that, for weaned suckled calves or yearling cattle which are 250 to 400 kg in the autumn and which are to be stored over the winter and turned out to pasture again in the spring, the optimum growth rate over the winter is around 0.7 kg live-weight gain/day for steers and 0.6 kg live-weight gain/day for heifers. When animals have been fed to achieve higher live-weight gains than these, most of the extra weight gained during the winter has been lost during the summer due to animals with the optimum rate of gain exhibiting compensatory growth at pasture. Conversely, when animals have been fed to achieve very low growth rates during the winter, although they have exhibited some compensatory growth during the following summer at pasture, the extent of this has been insufficient to compensate for the low growth rate during the winter. Consequently, the time taken to produce a finished animal has been significantly greater, and overall costs have been higher than for animals with the optimum growth rate over the winter (Steen, 1986; Lowman and others, 1996). For example, in the study undertaken by Keane and Drennan (1992b), when the live-weight gain of weaned suckled calves over the winter was increased from 0.38 to 0.66 kg/day by feeding 1.5 kg concentrates/head/day, only 25% of this extra live weight was lost due to compensatory growth by the lighter animals during the subsequent summer. On the other hand, when live-weight gain was further increased from 0.66 to 0.86 kg/day during the winter, 65% of the extra live-weight gain was lost due to compensatory growth over the summer.

The optimum live-weight gain of 0.7 kg/day for steers should be sustained by good quality silage (D-value over 70%) supplemented with zero to 1.0 kg concentrates/day, depending on how good the silage is, with average quality silage (D-value 63 to 67%) supplemented with 1.5-2.0 kg concentrates and with poor quality silage (D-value less than 62%) supplemented with 2.5 to 3.0 kg concentrates/day. Heifers require about 0.5 kg less concentrates/day than steers.

Optimum inputs of concentrates for finishing steers

The growth potential of the cattle

The potential of beef cattle for growth and lean meat deposition varies greatly depending on the gender and breed type of the animal. The response in growth rate to additional concentrates in the diet is greater in animals of high growth potential than in those of lower growth potential. For example, in two experiments at Hillsborough (Steen, 1995a; Steen and Kilpatrick, 1995) in which the energy intake of bulls and heifers of the same breed type was increased by 25% above the same basal diet, the response in carcass gain per unit of extra metabolisable energy was 64% greater in bulls than in heifers. Furthermore, a higher proportion of the additional feed energy was partitioned to fat in the heifers than in the bulls. Consequently in the bulls, 50% of the extra gain was lean meat while in the heifers only 33% of the extra carcass gain was lean meat. This resulted in the response in lean meat gain per unit of extra metabolisable energy consumed being two and a half times greater in bulls than in heifers.

The fact that heifers partitioned a greater proportion of the extra feed energy to fat because of their lower potential for lean meat deposition than the bulls, also explains the lower response in carcass gain to extra feed energy in the heifers, because about three times as much feed energy is required to produce each extra kg of fat as is required to produce each extra kg of lean meat.

These results clearly show that in terms of both growth rate and carcass composition, the optimum energy intake and hence the optimum intake of concentrates with silage-based diets is much higher for cattle of high growth potential than for those of lower growth potential. Therefore it is important that finishing cattle are grouped and housed according to their growth potential so that they can be given appropriate amounts of concentrates.

Effect of silage quality

A series of six experiments have been carried out at Hillsborough to examine the effects of offering finishing cattle different inputs of concentrates in addition to high and medium quality grass silages (Steen, 1988a and 1988b). As shown by the data in Table 10 in Chapter 4, the response in the performance of beef cattle to higher inputs of concentrates is much greater when lower quality silage is used as the basal forage than when high quality silage is fed. In those experiments, when concentrate input with the high digestibility silage was increased from 20 to 40% of total dry matter intake (i.e. 2.2 to 4.7 kg concentrates/day) an extra 23 kg of concentrates were required to produce an extra kg of carcass gain, and there was no further increase in carcass gain when the proportion of concentrates was increased above 40% of dry matter intake (i.e. 4.7 kg/head/day).

In contrast to this, when the amount of concentrates given with the medium digestibility silage was increased, there was a significant response in carcass gain up to the highest inclusion rate of 80% concentrates in the total dry matter intake (i.e. 9.5 kg of concentrates/head/day). In this case, 19 kg concentrates were required to produce each extra kg of carcass gain over the whole range of concentrate intake. Consequently when concentrate intake was increased from 20 to 80% of total dry matter intake the overall response in carcass gain with the medium digestibility silage was over three times the response obtained with the high digestibility silage. The results of this and other experiments clearly indicate that the optimum intake of concentrates is much lower when high digestibility silage is used than when medium or low digestibility material is used.

Data from experiments at Hillsborough over a period of 20 years have recently been brought together to produce a computer rationing programme which estimates the economic optimum inputs of concentrates for different types of cattle given grass silage-based diets with a wide range of silage qualities in terms of nutritive value and intake potential and with a wide range of concentrate intakes from zero to 90% of total dry matter intake (Kilpatrick and Steen, 1999).

Table 19 gives a general guide to the optimum levels of concentrate feeding for different types of cattle given silages of varying quality on farms on which there is sufficient silage available to offer silage ad libitum. High quality silage enables much lower levels of concentrates

TABLE 19 A GENERAL GUIDE TO OPTIMUM INPUTS OF CONCENTRATES (KG/DAY) FOR VARIOUS TYPES OF CATTLE GIVEN A RANGE OF GRASS SILAGES

	SILAGE QUALITY		
	GOOD	AVERAGE	POOR
FIRST CUT TAKEN	BEFORE 25 MAY	1-12 JUNE	AFTER MID-JUNE
D-VALUE	OVER 70	63-67	LESS THAN 62
Young bulls	4.0	7.0	8.5 or ad libitum
Heavy steers of high growth potential	3.0 – 3.5	6.0	7.5 or ad libitum
Steers of lower growth potential and heifers ofhigh growth potential	2.5	4.5	6.5
Heifers of low growth potential	1.5	2.5 – 3.0	4.0

to be used, while maintaining the same level of animal performance. Lower levels of concentrates are also optimum for cattle with limited growth potential as high concentrate inputs to these cattle results in the extra energy being partitioned mainly to fat deposition, as the animal does not have the genetic capacity to produce high daily gains of lean meat.

On the other hand, animals of high growth potential such as young bulls and large framed growthy bullocks, require relatively high inputs of concentrates to enable their potential for growth and lean meat deposition to be achieved, and to avoid the production of under-finished cattle which have a lower market value. As discussed below, it may be beneficial in some situations to feed less concentrates during the first part of the finishing period and more prior to slaughter rather than a flat rate throughout the finishing period, as this can improve carcass composition.

Economics of beef production and resources available on the farm

The optimum level of concentrate feeding for beef cattle also depends on the relative availability of different resources on the farm. For example, on farms with adequate land and storage for silage relative to the availability of finance, accommodation and labour for keeping large numbers of cattle, profitability is likely to be maximised by making best use of high quality silage and feeding only sufficient concentrates to optimise the performance of the limited number of cattle on the farm.

Conversely, when land and storage for silage are limited relative to the availability of finance, accommodation and labour for keeping large numbers of cattle, it may be economical to feed only a small quantity of silage/head/day and high inputs of concentrates to enable more cattle to be finished. The extent to which it is profitable to do this depends on the overall profitability of beef production. If the overall profitability of beef finishing is high, then it may be profitable to feed little or no silage and finish large numbers of cattle on high-concentrate diets using straw or other forage as a source of roughage to maintain healthy digestion. However if the overall profitability of beef finishing is low, with an unfavourable price for beef relative to the price of store cattle and concentrates, then the use of high-concentrate diets to finish large numbers of cattle is unlikely to be economically feasible.

Another finding from the work of Steen and others (2002) (Table 10 in Chapter 4), was the fact that the performance of individual cattle given high-concentrate diets was extremely variable. Some bullocks responded very well to the highest input of concentrates with live-weight gains of 1.8 kg/day, while others responded poorly with live-weight gains as low as 0.8 kg/day. In general, cattle which are exhibiting compensatory growth, because they have been on a moderate to low plane of nutrition before going unto the high-concentrate diet, respond best to the high input of concentrates.

However cattle will generally only exhibit high levels of compensatory growth for about 60 to 80 days and then growth rate declines significantly. This was demonstrated in a recent experiment at Grange Research Centre, in which 500 kg Charolais bullocks were given a high-concentrate diet for either 12 or 23 weeks (Kelly, 2000). During the first 12 weeks of the experiment the animals had live-weight and carcass gains of 1.42 and 1.04 kg/day respectively, while during the next 11 weeks live-weight and carcass gains declined to 1.16 and 0.84 kg/day respectively, even though concentrate intake was 12% higher than in the first 12 weeks. **Consequently, about 40% more concentrates were required to produce each kg carcass gain during weeks 12 to 23 than during the first 12 weeks.**

Cattle which are exhibiting compensatory growth following a low plane of nutrition previously, have also been found to have a lower fat content in their carcass gain (Wright and Russell, 1991; Steen and Kilpatrick, 2000). This, combined with a high food intake can explain their higher growth rate, as only about one third of as much food energy is required to deposit one kg lean meat as for one kg of fat. Consequently, the phenomenon of compensatory growth can be used to reduce the fat content in the carcasses of cattle given high energy diets prior to slaughter. This was demonstrated in an experiment at Hillsborough during the early 1990s (Steen and Kilpatrick, 2000) in which continental cross steers were given silage and a low input of concentrates during a long finishing period, or silage only during the first part of the finishing period and silage plus a relatively high concentrate input during the last 50 to 80 days before slaughter. The two groups of cattle had similar total food intakes and live-weight and carcass gains, but those given the high input of concentrates prior to slaughter produced less fat than those which received a constant input of concentrates throughout the finishing period.

This finding has been substantiated by recent work undertaken at Grange Research Centre in which both Charolais and Friesian steers were given either a flat rate of concentrate feeding (5 kg/day) throughout a five month finishing period or were given concentrates ad libitum during the second half of the finishing period (Kelly, 2000). Again, total food intakes and growth rates were similar for the two patterns of concentrate feeding, but the cattle given concentrates ad libitum during the second half of the finishing period produced carcasses with a lower fat classification than those produced by the cattle which received the constant input of 5 kg concentrates/day over the entire finishing period. **Consequently, in situations in which high-concentrate diets are being used for finishing steers and heifers, it is generally preferable, in terms of both feed efficiency (and hence the cost of carcass gain) and carcass composition, that these diets are fed only during the last two to three months before slaughter.**

The optimum protein content in concentrates for beef cattle given silage-based diets

Protein content of concentrates for young growing cattle

Because young animals are still actively growing, they have a higher requirement for protein relative to energy, than older finishing cattle. This combined with the fact that weaned suckled calves and yearling cattle which are being stored over the winter on silage-based diets generally require only a relatively low input of concentrates to achieve an optimum live-weight gain of 0.6 to 0.7 kg/day, has resulted in these animals giving good responses in growth rate to the inclusion of protein supplements in the concentrates in several experiments at Grange, Hillsborough and elsewhere (Keane and Drennan, 1980, 1981 and 1982; Steen, 1989 and 1992b; Petit and others, 1994). Feeding a smaller quantity of an 18% crude protein meal has been more economical than feeding a larger quantity of a low protein supplement to achieve the same level of performance (Steen, 1992b). Therefore concentrates containing approximately 18% crude protein should be most economical for suckled calves and yearlings which are being stored over the winter on silage-based diets prior to being turned out to grass again in the spring.

In a number of experiments young cattle have been over-wintered very satisfactorily at relatively low cost on a diet of grass silage supplemented with maize gluten feed plus minerals and vitamins (e.g. Keane and Drennan, 1990; Steen, 1992b and 1993b).

Effects of the protein content of concentrates for finishing cattle

A series of eight experiments were carried out at Hillsborough to examine the effects of supplementing silage-based diets with protein for finishing steers which were approximately 400 kg live weight at the beginning o f the experiments (Steen, 1988c; Steen and Moore, 1988; 1989; Steen, 1996a; R.W.J. Steen, unpublished data). The silages were well preserved with protein contents ranging from 11 to 17% and D-values from 66 to 73%. In each experiment, the silages were supplemented with 2.4 to 3.6 kg/head daily of either mineralised barley or mixtures of barley and soyabean meal or barley and fish meal containing about 17% crude protein for periods of 98 to 155 days. Increasing protein intake did not affect silage intake or animal performance in any of the eight experiments, but significantly increased carcass fatness, these effects being consistent across six of the eight experiments (Table 20). The increase in carcass fatness as a result of increasing protein intake, was greatest in animals with the lowest growth potential and therefore the lowest requirement for protein.

In an experiment at Edinburgh, Lowman and others (1985) obtained similar effects, in that supplementation of a silage-based diet with protein did not increase the carcass gain of non-implanted steers and heifers and tended to increase carcass fatness.

Protein in feedstuffs is composed of what is termed effective rumen degradable protein (or ERDP) and undegradable dietary protein (or UDP). Effective rumen degradable protein is that part of the protein which is

TABLE 20 THE EFFECTS OF PROTEIN SUPPLEMENTATION OF SILAGE-BASED DIETS ON THE PERFORMANCE AND CARCASS FATNESS OF STEERS (SUMMARY OF EIGHT COMPARISONS)

		PROTEIN IN CONCENTRATES (%)	
		9.4	17.6
Silage dry matter intake (kg/day)		5.6	5.6
Live-weight gain (kg/day)		1.02	1.01
Carcass gain (kg/day)		0.61	0.60
Carcass fat classification*	3	90%	60%
	4	10%	40%
Subcutaneous fat depth (mm)		6.6	7.4
Marbling score**		2.9	3.4
Saleable meat in carcass (%)		70	69
Fat trim (%)		10	11

*5 point scale, 1 = leanest, 5 = fattest
**8 point scale, 1 = leanest, 8 = fattest

broken down by, and available to, the microbes in the rumen. An adequate supply of ERDP is essential to enable the microbes to digest fibre, starch and other sources of energy in the rumen. Undegradable dietary protein is that part of the protein in the diet which is not utilized by the rumen microbes, and so passes through the rumen of the animal to the intestine, where it can be absorbed and used directly by the animal.

The Metabolisable Protein System has been developed in the UK to provide a basis for assessing the requirements of cattle for ERDP and UDP. In four of the experiments at Hillsborough described above, for which ERDP and UDP intakes were estimated, the higher intake of protein was required to meet the animals' requirements for ERDP, while the diets of silage supplemented only with barley provided only 80 to 85% of ERDP requirements. However, the fact that there was no increase in diet digestibility, silage intake or live-weight or carcass gain in these experiments when protein intake was increased, would indicate that the requirements of the cattle for ERDP on these experiments were lower than those given by the UK Metabolisable Protein System.

As well as wasting protein, feeding the higher protein concentrates also tended to reduce carcass quality and increased the excretion of nitrogen from the animal by over 20%. Excretion of excessive nitrogen by cattle is currently of concern because of the potential detrimental effects of nitrogen in cattle slurry on the environment.

A further four experiments were carried out at Hillsborough, to examine the effects of adding protein to diets of silage supplemented with barley for finishing, continental-cross heifers (Steen and Robson, 1995; Steen, 1996d). The silages were well preserved and of medium to high digestibility with D-values of 64 to 73%. They were supplemented with 2.0 to 4.5 kg/head/day of either fortified barley or mixtures of barley and soyabean meal (19% crude protein). Increasing the protein content of the concentrates from 10 to 19% did not affect live-weight or carcass gain or carcass fatness as indicated by fat classification, subcutaneous fat depth, marbling score or the yield of saleable meat in the carcass. However the higher protein concentrates tended to reduce the lean content and increase the fat content of the fore-rib joints which were totally dissected.

TABLE 21 THE EFFECT OF PROTEIN SUPPLEMENTATION ON THE PERFORMANCE OF SUCKLED BULLS GIVEN SILAGE-BASED DIETS. (AVERAGE RESULTS OF THREE EXPERIMENTS; DRENNAN AND OTHERS, 1994)

	CONCENTRATE	
	BARLEY	BARLEY/SOYABEAN MEAL
Protein content of concentrate (%)	10.5	13.0
Concentrate intake (kg/day)	4.1	4.1
Silage intake (kg DM/day)	4.3	4.3
Initial live weight (kg)	304	303
Slaughter live weight (kg)	604	597
Dressing percentage	58.4	58.0
Carcass weight (kg)	353	347
Live-weight gain (kg/day)	1.27	1.24
Carcass gain (kg/day)	0.78	0.76
Carcass fat classification*	2.7	2.8
Carcass conformation classification**	4.1	3.8

*5 point scale: 1 = leanest, 5 = fattest
**5 point scale: 1 = worst, 5 = best

Nevertheless, the detrimental effects of increasing protein intake on carcass fatness were less, and more variable in heifers than in steers, even though heifers would be considered to have a lower growth potential and hence a lower requirement for protein than steers. Other research would indicate that these effects are likely to be attributable to the different hormone balances in the animals.

Two experiments have also been carried out at Hillsborough to compare mineralised barley and mixtures of barley and soyabean meal (16.5% crude protein) as supplements to silage for finishing bulls (Steen, 1991b). The silages were well preserved and of high digestibility (D-value 73%). The bulls were mainly continental cross Friesian and a few Friesian, and were initially 12 months old and about 400 kg live weight. Increasing the protein content of the concentrates from 9 to 16%, did not affect live-weight or carcass gain in one of the experiments, but increased carcass gain by 12% (0.75 versus 0.67 kg/day) in the other experiment. In the first experiment in which there was no response to protein, the bulls were reared indoors and had a high live-weight gain prior to the experiment, while in the second experiment, the bulls had been at pasture for about six months before the experiment, and consequently would have been exhibiting compensatory growth during the experimental period, which would have increased their requirement for protein.

A further three experiments were carried out at Grange Research Centre to examine the effects of supplementing grass silage with approximately 4 kg of either mineralised barley or mixtures of barley and soyabean meal for continental weaned suckled bulls (Drennan and others, 1994). The silages were well preserved and of medium to high digestibility and contained 12 to 15% crude protein. The bulls were initially about 300 kg live weight and the experimental diets were fed until slaughter at 560 to 620 kg live weight. As shown in Table 21, feeding a mixture of barley and soyabean meal rather than barley did not increase live-weight or carcass gains in any of the experiments and did not improve carcass fatness or conformation.

Effect of silage quality on the optimum protein content of silage-based diets for finishing cattle

Although there was no response in the performance of finishing steers and heifers to additional protein in the experiments listed above, and a positive response in the performance of young bulls was obtained in only one out of five experiments, it should be noted that the silages used in these experiments were well preserved, of medium to high digestibility and generally contained at least 12% crude protein. There are indications from other research (e.g. Kirby and others, 1983; Waterhouse and others, 1985) that finishing cattle given silages with lower digestibility (i.e. D-value less than 65%) and/or a low protein content (i.e. less than 12%) can give positive responses in performance to supplementary protein. Low digestibility silages generally have a lower protein content than higher digestibility silages, and the protein in the lower digestibility silage also has a lower digestibility and so less of it is available to the animals. A poor fermentation in silage can also reduce the availability of the protein in the silage to the animal (Steen, 1990).

Consequently, when finishing cattle are given well preserved grass silage of medium to high digestibility (D-value at least 65%) containing at least 12% protein, they are unlikely to give a positive response in performance or carcass composition if the protein content of supplementary concentrates is increased above about 10%. However when silages with a lower digestibility (i.e. D-value less than 65%) and/or a lower protein content (i.e. less than 12%) are used, especially if they are poorly preserved, then research findings would indicate that finishing cattle may give an economic response in performance to increasing the protein content in the concentrates from 10 to about 15%. As maize silage usually has a very low protein content, much higher levels of protein are generally required in supplementary concentrates given with maize silage, depending on how much concentrates are being fed.

Optimum protein content of high-concentrate diets for finishing cattle

Many experiments involving large numbers of cattle have been carried out in the United States to examine the effects of varying the protein content of high-concentrate diets for finishing beef cattle, and the results of several of these have been reviewed by Galyean (1996). The results generally indicate that non-implanted steers and heifers (Galyean, 1996) and young bulls (Martin and others, 1978; Williams and others, 1975) have given positive responses in performance when the protein content of the diet has been increased to 11% on a fresh weight basis (13% on a dry matter basis), and that there has generally been no further positive effect on performance or carcass composition when the protein content of the concentrates was increased above 12% on a fresh weight basis (i.e. 14% on a dry matter basis). In some of the experiments, increasing the protein content above 12% on a fresh basis, increased carcass fatness, which is in line with the results obtained at Hillsborough with silage-based diets.

Thus the results of experiments with high-concentrate diets, would indicate that the optimum protein content in high-concentrate diets given to finishing cattle is approximately 12% on a fresh weight basis (i.e. 14% ona dry matter basis).

SUMMARY OF THE MAIN POINTS ON OPTIMUM USE OF CONCENTRATES

1. The optimum level of concentrate feeding for beef cattle depends on a number of factors:

   (a) Whether the cattle are to be finished or stored over the winter and turned out to pasture again in the spring.

   (b) The growth potential of the cattle.

   (c) The quality of the silage or other forage being fed.

   (d) The overall economics of beef production and the availability of silage and other resources on the farm.

2. The optimum level of concentrate feeding for weaned suckled calves and yearlings which are to be turned out to grass again in the spring normally varies between 1.0 and 3.0 kg/day depending on silage quality.

3. The optimum level of concentrate feeding for finishing cattle normally varies according to the quality of the silage available and the growth potential of the cattle as shown in Table 19.

4. On farms with limited land and/or storage for silage, it may be economical to use high-concentrate diets for finishing cattle depending on the overall economics of beef production.

5. Cattle of high growth potential generally respond well to feeding a high-concentrate diet for about 2 to 3 months, but performance usually declines substantially after a longer period of high-concentrate feeding.

6. Feeding a very low input of concentrates or only silage for the first half of the winter followed by a high-concentrate diet for 2 to 3 months can improve carcass composition compared to feeding the same total quantity of concentrates as a moderate daily input over the whole winter.

7. It has generally been more economical to feed a low input of a high-protein concentrate (around 18% protein) to weaned suckled calves and store cattle than to feed a higher input of a low-protein concentrate.

8. With reasonably good quality silage, finishing steers and heifers have not produced a positive response to increasing the protein content of concentrates above 10% as shown in Table 20.

9. Cattle given low digestibility silage (i.e. D-value less than 65%) and/or silage with a low protein content (i.e. less than 12% protein) have given positive responses in performance to increasing the protein content of concentrates up to 15 or 16%.

10. As maize silage usually has a very low protein content, much higher levels of protein are generally required in concentrates fed with maize silage. The optimum protein content depends on how much concentrates are fed.

11. The optimum protein content of high-concentrate diets for finishing cattle has generally been about 12% on a fresh weight basis (i.e. 14% of dry matter).

CHAPTER 7

THE VALUE OF DIFFERENT SOURCES OF CONCENTRATES FOR BEEF CATTLE

Feedstuffs are generally evaluated in terms of their chemical analysis, such as protein, oil, fibre and ash contents, and using data from metabolism studies. However, when individual feedstuffs are given to beef cattle as supplements to grass silage, they may have different effects on the digestion of the silage in the diet, and hence on the amount of energy which the cattle obtain from the silage component of the ration. Consequently individual feedstuffs may have either higher or lower feeding values as supplements to grass silage, than when they are included in high-concentrate diets, or than their chemical analysis would suggest.

A wide range of feedstuffs have been fed to beef cattle at Hillsborough, as supplements to grass silage, and their feeding values have been determined in terms of the level of performance which they have sustained in the animals as a component of this type of diet. Similarly, a wide range of feedstuffs have been evaluated at Grange and other Research Centres, as components of high-concentrate diets given to beef cattle. When comparing feedstuffs, barley is normally taken as the standard source of energy, while soyabean meal 50 is taken as the standard high-protein feed, and other feedstuffs are evaluated relative to barley and soyabean meal as shown in Table 22.

TABLE 22 PROTEIN AND ESTIMATED METABOLISABLE ENERGY CONTENTS OF FEEDSTUFFS AS COMPONENTS OF BEEF CATTLE RATIONS

	PROTEIN CONTENT (%)	ESTIMATED EFFECTIVE METABOLISABLE ENERGY CONTENTS OF FEEDSTUFFS IN BEEF CATTLE RATIONS RELATIVE TO BARLEY = 100	
		AS A SUPPLEMENT TO GRASS SILAGE	IN HIGH-CONCENTRATE DIETS
Barley (14% MC)	9.5	100	100
Barley (18% MC)	9	95	95
Wheat (14% MC)	11	100	100
Maize meal	8.5	116	105
Maize gluten feed	18	93	93
Maize germ meal	10	92	110
Molassed sugarbeet pulp	9	93	93
Citrus pulp	6	93	93
Molasses (Cane)	4	70	70
Soyabean meal 50	46	102	102
Maize distillers dark grains	26	100	105
Cottonseed cake	30	78	75
Copra meal	20	90	90
Sunflower meal	27	63	63
Rapeseed meal	34	80	80

Kennelly and others (1988) carried out a series of experiments to compare dried barley and barley with a higher moisture content. The overall results of these and earlier studies indicated that dried barley and high-moisture barley had similar feeding values per unit of dry matter.

Energy sources with relatively low protein contents

Wheat

The chemical composition of wheat and the results of digestibility experiments would indicate that it should have a feeding value about 6% greater than that of barley. However from the results of beef cattle feeding experiments, it has been calculated that the average feeding value of wheat has been only the same as that of barley, as a supplement to both grass silage and hay (Thomas and Geissler, 1968; Dion and Seoane, 1992; Steen, 1993a; Drennan and Moloney, 1998) and as a component of high-concentrate diets (Oltjen and others, 1966; Pullar, 1995). Furthermore, there is a greater risk of digestive upsets when feeding wheat rather than barley. Consequently, wheat should be introduced to the diet gradually, and it is preferable to use rolled or coarsely ground wheat, as finely ground wheat may increase the risk of digestive upsets.

The high content of rapidly digested starch in wheat and to a lesser extent in barley, may result in a surge of acid production in the rumen or main stomach of beef cattle, especially if they are given wheat or barley in one large feed per day. This in turn may increase the acidity of the animals blood and cause lameness due to laminitis in their feet. Consequently when cattle are given diets containing a high proportion of concentrates, it is preferable that at least one third of the concentrates should be composed of ingredients which have either a low starch content such as maize gluten feed, citrus pulp or sugarbeet pulp, or starch which is digested more slowly in the rumen, such as that of maize meal.

Maize meal

The feeding value of maize meal, as determined in digestibility studies, has generally been reported to be about 7% higher than that of barley. However in four experiments at Hillsborough (Steen, 1996b), the feeding value of maize meal in terms of the live-weight and carcass gains which it sustained in beef cattle, has been 16% higher than that of barley. Furthermore, when finishing cattle, especially those given relatively high inputs of concentrates as a supplement to silage, have been given 16% more barley than maize to equalise energy intake, the cattle given barley ate less silage because of the higher concentrate intake. Consequently, 25 to 30% more barley than maize meal has been required to sustain the same level of carcass gain, due to the lower silage intake with the higher input of barley. However when cattle were given only modest inputs of concentrates, feeding extra barley to equalise animal performance, produced a smaller depression in silage intake, and so only 15 to 20% more barley than maize was required to achieve the same level of animal performance. Thus the monetary value of maize varies from about 15 to 25% above that of barley, depending on the type of diet in which it is included and the type of cattle to which it is being fed. **Thus maize meal has been found to be an excellent feed for finishing cattle especially those of high growth potential.**

However when included as a component of high-concentrate diets for beef cattle, maize has had an average feeding value of only 5% above that of barley and wheat, although there has been quite a lot of variability in its feeding value relative to that of barley and wheat in different experiments (e.g. Oltjen and others, 1966; Zinn, 1993; Mathison and Engstrom, 1995).

Cereal by-products (maize gluten feed, maize distillers dark grains and maize germ meal)

Maize gluten feed

Maize gluten feed is one of the cereal by-products most commonly used in Northern Ireland, and its feeding value has been evaluated in six experiments at Hillsborough (Steen, 1992b; 1993b and 1995b) and in two experiments at Grange (Keane and Drennan, 1990). In experiments with young growing cattle, maize gluten feed has had a feeding value equivalent to 93% of that of a 17% barley/soyabean meal concentrate, while in diets for finishing cattle which did not require the high protein content in maize gluten feed, it had a feeding value equivalent to 93% of that of barley. Thus the monetary value of maize gluten feed depends on whether or not the cattle require the additional protein in gluten compared to the lower protein content of barley. As the quality of maize gluten feed can vary it is important to define the maize gluten used. In the studies at Hillsborough, it contained 19% crude protein, 13% acid detergent fibre and 12% starch on average over the six experiments.

Maize gluten feed has also been evaluated as a feed for beef cattle in several experiments involving high-concentrate diets (e.g. Keane and Drennan, 1988; Hannah and others, 1990; DiCostanzo and others, 1990; Ham and others, 1995). The average feeding value of maize gluten feed in high-concentrate diets has also been calculated to be equivalent to 93% of that of barley, but there has been considerable variation from 84 to 102% of the feeding value of barley, depending on the quality of the maize gluten feed.

Weiss and others (1989) reviewed the results of 31 experiments which were carried out in the United States to examine the feeding value of maize gluten feed. These experiments involved over 2700 cattle, and the findings of the review were in line with the results of the experiments at Hillsborough and Grange, but again there was considerable variation between individual experiments.

Maize gluten feed is more acidic than most other sources of concentrates, with pH values of around 4.2. Consequently, there has been some concern about the effects of feeding maize gluten feed with acidic silages (i.e. those with low pH values). However in experiments at Hillsborough it was found that, although maize gluten feed had a low pH, it did not produce as low a pH in the rumen of the animal, as that produced by cereal-based concentrates. This may well be attributable to the fact that the high-starch content in the cereals was rapidly fermented in the rumen and this produced large quantities of acid, while maize gluten feed has a low starch content and therefore produced less acid. Consequently, on average over six experiments the intake of low pH silages has actually been about 5% higher when they have been supplemented with maize gluten feed than when they were supplemented with barley.

Maize distillers dark grains

Maize distillers dark grains have a high energy content. However they also have a relatively high oil content of about 8%. When used as a supplement to good quality silage the digestibility of the fibre in the silage part of the ration has been reduced, presumably due to the oil in the distillers grains. Consequently when used as a supplement to grass silage, maize distillers grains have had an effective energy content similar to that of barley (e.g. Steen, 1995b). However their relatively high protein content (about 26%), gives them a monetary value somewhat higher than barley, depending on the cost of other sources of protein.

Maize germ meal

Maize germ meal has a high energy content due to its high oil content. It usually has an oil content of about 10%, and an energy content, 10 to 12% higher than that of barley. However the value of maize germ meal as a

TABLE 23 A COMPARISON OF MAIZE GLUTEN FEED AND MAIZE GERM MEAL AS SUPPLEMENTS TO GRASS SILAGE (STEEN, 1995B)

	CONCENTRATE TYPE		
	BARLEY/SOYA	MAIZE GLUTEN FEED	MAIZE GERM MEAL
Concentrate intake (kg/day)	4.6	4.6	4.6
Silage intake (kg DM/day)	5.5	5.6	4.8
Digestibility of total ration (%)	78	75	72
Live-weight gain (kg/day)	1.45	1.40	1.29
Carcass gain in 120 days (kg)	105	102	95

feed for beef cattle depends on the type of diet in which it is included.

When maize germ meal has been included as a supplement with good quality grass silage for finishing cattle, the digestibility of the fibre in the silage has been greatly reduced, presumably due to the high oil content in the maize germ inhibiting the digestion of fibre in the rumen. In two experiments at Hillsborough, the reduction in the fibre digestibility of the diet, and the consequent reduction in silage intake when maize germ meal was used as a supplement to silage, resulted in the diet containing maize germ meal producing 7% less carcass gain (7 kg in 120 days) than when maize gluten feed was used as a supplement, even though the energy content of the maize germ meal was about 12% higher than that of maize gluten feed as shown in Table 23. Consequently, when used as a supplement to good quality grass silage, maize germ meal had a monetary value equivalent to only 90-95% of that of barley.

On the other hand, when cattle are given diets which are almost entirely composed of concentrates with very little silage, maize germ meal should have a higher feeding value, about 5 to 10% higher than that of barley, as there would be little overall impact on diet digestibility. These results also clearly demonstrate that the value of a feedstuff as a supplement to grass silage, depends not only on the energy and protein contents of the feedstuff itself, but also on the effect which the feedstuff has on the amount of nutrients which the animal obtains from the silage part of the ration.

Other by-products (sugarbeet pulp, molasses, citrus pulp, soya hulls)

Sugarbeet pulp and citrus pulp

In experiments at Grange Research Centre and in France, unmolassed sugarbeet pulp has had an energy value for beef cattle equivalent to 96% of that of barley (e.g. Muller and others, 1985; Muller and Beranger, 1985), while in studies at Grange and Hillsborough, molassed sugarbeet pulp and citrus pulp have both had an energy content equivalent to 93% of that of barley in beef cattle rations (Drennan, 1990; Steen, 1993b and 1995b). As the protein contents of unmolassed and molassed sugarbeet pulp are similar to that of barley, they should have a monetary value equivalent to 93 to 96% of that of barley, while citrus pulp should have a monetary value of approximately 90% of that of barley when its lower protein content is taken into account.

Sugarbeet pulp and citrus pulp are both very palatable feeds for cattle and are very useful sources of energy in rations for calves, store cattle and finishing cattle receiving moderate inputs of concentrates, especially in situations where a very palatable concentrate is needed to encourage the animals to eat it. They also have the benefit that silage intake has been slightly higher when pulp has been fed rather than barley. However when cattle of high growth potential are receiving large quantities of concentrates, with the aim of achieving very high live-weight gains, the inclusion of a large proportion of citrus or beet pulp in the ration may limit performance due to their lower energy content. Nevertheless, the inclusion of up to 33% pulp in cereal-based rations which are fed at high levels to finishing cattle may be very beneficial, as this should reduce the rate of acid production in the rumen from the fermentation of starch in the cereals, which in turn should reduce the risk of digestive upsets or laminitis occurring.

Molasses

The feeding value of molasses in the diet of growing and finishing cattle has been examined in a series of 13 experiments at Grange and Moorepark research centres (Drennan, 1985 and undated) and in studies in Continental Europe (Karalazos and others, 1985). The feeding value of molasses in these experiments, calculated from the growth rates which it sustained, was somewhat lower than its chemical analysis would suggest. Furthermore, the feeding value of molasses has been found to decline as the quantity consumed/animal/day increased.

When included in diets at up to 2.5 kg/head/day, molasses has had an effective energy content equivalent to 70% of that of barley, which combined with its low protein content, has given it a monetary value equivalent to approximately 67% of that of barley. However at higher levels of intake it has had a monetary value equivalent to only 60% of that of barley.

Soya hulls

The limited amount of information available on the feeding value of soya hulls for beef cattle would indicate that they have an effective energy content equivalent to about 80 to 85% of that of barley when included as a component of a high-concentrate diet (e.g. Ludden and others, 1995). However there has been considerable variation in their feeding value in different experiments, and the results of some experiments in which a smaller quantity of soya hulls have been included in high-forage diets for beef cattle would indicate that they may have a somewhat higher feeding value in some high-forage diets (e.g. Hibberd and Chase, 1986; Anderson and others, 1988a and 1988b; Hsu and others, 1987; Horn and others, 1995).

High-protein oilseed meals (soyabean, rapeseed, cottonseed and sunflower meals)

These feedstuffs are the meals which are produced after the oil has been extracted from oilseeds. Of the four oilseed meals which are most readily available in this country (i.e. soyabean, rapeseed, cottonseed and sunflower meals), soyabean meal 50 has a much higher feeding value than the other three, with an average protein content around 46% and an effective energy content similar to or slightly higher than that of barley.

Rapeseed meal

Rapeseed meal has been found to contain antinutritional substances known as glucosinolates (Bell, 1993), which have been shown to reduce food intake and performance of livestock (McGee, 1998). Rapeseed meal which has been manufactured from rapeseed with a low content of glucosinolates, has been found to have an effective energy content equivalent to 80% of that of barley in a limited number of animal production experiments, when included in the diet at a rate of up to 0.6 kg/day (i.e. up to 10% of total dry matter intake) (e.g. Grundy and others, 1996). Because of the presence of antinutritional factors in rapeseed meal, caution should be exercised regarding the inclusion of more than 10% rapeseed meal in the total diet. Furthermore, the results of research have indicated that the inclusion of rapeseed meal in the diet can have a detrimental effect on the fertility of breeding stock (McGee, 1998).

Cottonseed and sunflower meals

The results of experiments at Hillsborough indicate that cottonseed meal and sunflower meal are low digestibility feeds with low energy contents (Steen, 1989; Steen, 1993b). In beef cattle production studies cottonseed meal has had an average effective energy content equivalent to 76% of that of barley, while sunflower meal has had a very low effective energy content equivalent to only 63% of that of barley. The chemical composition and energy content of cottonseed and sunflower meals can very considerably, and therefore either higher quality or lower quality meals than those used in these experiments may be available. Nevertheless, the meals used in these experiments were typical of those imported into this country, and therefore, in general, cottonseed meal or sunflower meal are not suitable for inclusion in rations for finishing cattle because their energy content is too low.

However their relatively high protein contents, mean that they can be a useful source of protein for young growing cattle or suckler cows provided that they are competitively priced. To be competitive with soyabean meal as a source of protein, the price of cottonseed meal should be less than 70% of that of soyabean meal while the price of sunflower meal should be less than 55% of that of soya. Even then, other sources of protein such as maize gluten feed, maize distillers grains or copra meal may be more competitively priced.

Copra meal and palm kernel meal

Copra and palm kernel meals are produced when oil is removed from coconuts and palm kernels respectively. There is very limited information from animal production experiments involving these feeds. The limited amount of data which is available would suggest that copra has an effective energy content of about 90% of that of barley, while palm kernel meal has a somewhat lower energy content equivalent to 75 to 80% of that of barley.

Thus, palm kernel meal is of limited suitability for rations for finishing cattle. Copra or palm kernel meals with high residual oil contents may have slightly higher feeding values than those listed above, when they are included as components of high-concentrate diets, but this is unlikely to enhance their feeding value as components of silage-based diets. As copra and palm kernel meals can be less palatable than many of the other feedstuffs, it is prudent to keep their rate of inclusion in concentrates fairly low.

When by-product feedstuffs are being purchased, especially if large quantities are involved, it is generally advisable to have a representative sample analysed, as their composition can vary considerably. Similarly, when purchasing compound feedstuffs, it is important to ascertain which ingredients they contain, as two concentrates with the same energy and protein contents may have very different feeding values as supplements to grass silage, as discussed earlier.

The effects of feeding silage and concentrates as a complete diet on the performance of beef cattle

The effects of mixing silage and concentrates in a mixer wagon to produce a complete diet rather than feeding concentrates once per day, separate from the silage, have been examined in three experiments at Hillsborough and Grange Research Centres. In the two experiments at Hillsborough feeding a complete diet rather than feeding concentrates once per day had little or no effect on animal performance when finishing cattle of 400 to 650 kg live weight were given 2.5 to 3.5 kg concentrates/head daily in addition to good quality silage. However when concentrate intake was increased to 6 to 7 kg/head daily, feeding a complete diet increased silage intake by 20% and increased carcass gain by 15% compared to once daily feeding of concentrates. Very similar results were obtained in the experiment at Grange as shown in Table 24, except that in this case complete diet feeding did not increase silage intake, but it still increased carcass gain by 15% at the higher level of concentrate feeding (Drennan, 1990). In the experiments at Hillsborough, the method of feeding did not affect carcass fat content, but feeding a complete diet tended to increase the deposition of internal fat which is not included in the carcass.

Overall the results of these studies indicate that when finishing cattle are given moderate inputs of concentrates (i.e. up to 4 kg/head daily or up to 40% of total dry matter intake) the use of complete diet feeding rather than feeding concentrates once per day is unlikely to have a significant effect on animal performance or carcass composition. However when high inputs of concentrates are used, so that concentrates constitute 50% or more of total dry matter intake (i.e. over 5 kg concentrates/head daily for typical finishing cattle), complete diet feeding is likely to result in a substantial increase in performance, compared to feeding concentrates once per day. Research information from Grange would indicate that feeding concentrates twice per day may produce about half of the response which is obtained from complete diet feeding (Drennan and Moloney, 1998).

It is also important to consider that in addition to the increase in the performance of beef cattle as a result of using a complete diet, complete diet feeding provides additional potential benefits which may not be available when silage and concentrates are fed separately. These include the opportunity to mix two or more forages, to incorporate wet by-products into the diet and the facility to mix concentrate straights or other ration components on the farm with a low input of labour. The use of complete diets can reduce the labour requirement for

TABLE 24 A COMPARISON OF FEEDING CONCENTRATES ONCE/DAY AND COMPLETE DIET FEEDING FOR FINISHING BEEF CATTLE (DRENNAN, 1990)

	CONCENTRATE FEED LEVEL			
	LOW		HIGH	
METHOD OF FEEDING CONCENTRATES	ONCE/DAY	COMPLETE DIET	ONCE/DAY	COMPLETE DIET
Concentrate intake (kg/day)	2.7	2.7	5.2	5.2
Total feed intake (kg DM/day)	8.9	8.8	9.4	9.3
Carcass gain (kg/day)	0.44	0.46	0.52	0.60

feeding cattle compared to feeding silage and concentrates separately and also eliminates the need for separate troughs for feeding concentrates.

Rationing beef cattle

The ability to determine the correct level of feeding for beef cattle, which is required to achieve the optimum level of performance, can improve the efficiency and profitability of the enterprise. As the intake of grass silage, which forms the basis of winter rations for the majority of beef cattle in Northern Ireland, can be variable, an effective method of predicting the voluntary intake of silage from its chemical and biological composition is the first step in determining the correct amount of concentrates to be fed. For this reason a major research programme was undertaken at Hillsborough with the aim of developing an effective, low-cost system for predicting the silage intake of different types of cattle (Steen and others, 1998). The results of this research have been used to develop the Hillsborough Feeding Information System, which is now commercially available to farmers, and which provides an analysis of the silage, a prediction of the intake potential of the silage and some basic information on rationing beef cattle which are given the silage.

The results of feeding experiments carried out at Hillsborough over a 15 year period and involving 3000 to 4000 cattle, have also been used to produce a computer rationing programme which predicts the performance of different types of cattle (i.e. bulls, steers and heifers of various breed types and growth potentials over the live weight range from 100 to 750 kg) given diets ranging from silage with no concentrates right through to all-concentrate diets. Alternatively the programme predicts the quantity of concentrates required by different cattle given particular silages, to achieve a desired growth rate. This programme is currently available from the Institute at Hillsborough.

SUMMARY OF THE MAIN POINTS ON THE VALUE OF DIFFERENT SOURCES OF CONCENTRATES FOR BEEF CATTLE

1. The value of different sources of concentrates as feeds for beef cattle given silage-based diets depends not only on the protein and energy contents of the feedstuff but also on how each feedstuff affects the utilization of the energy in the silage component of the ration.
2. Therefore the value of individual feedstuffs varies depending on whether they are fed as part of a forage-based diet or as part of a high-concentrate diet as shown in Table 22.
3. Two feedstuffs can have the same energy and protein contents but very different feeding values as components of silage-based diets.
4. For example, maize meal has a very high feeding value as a component of a silage-based diet while maize germ meal has a low feeding value as a component of a silage-based diet.
5. Complete diet feeding can provide a number of practical benefits in feeding a large number of cattle. It can increase the range of diets which can be fed and it can improve the performance of cattle which are given high inputs of concentrates.

CHAPTER 8

COMPARISON OF BULLS, STEERS AND HEIFERS FOR BEEF PRODUCTION

Two major experiments were undertaken at Hillsborough to compare bulls, steers and heifers reared under the same management (Steen, 1995; Steen and Kilpatrick, 1995). The cattle which were continental cross Friesian, were born in the autumn, were at pasture for one summer and were slaughtered at the end of their second winter at about 18 months of age. During the second winter they were given a complete diet consisting of two-thirds grass silage and one-third concentrates on a dry matter basis. The results of these experiments are summarised in Table 25.

Comparison of bulls and steers

During the finishing period bulls consumed 4% more food than steers, but had an 18% higher live-weight gain and 30% higher rate of carcass gain than steers. Over their entire life, bulls produced 43 kg or 14% more carcass weight than steers. Carcasses of bulls were also leaner than those produced by steers, bull carcasses having 66% lean meat compared to 63% lean in steer carcasses. The lower fat content in carcasses from bulls was reflected in a higher yield of saleable meat and less fat trim from these carcasses when they were boned out in the meat

TABLE 25 A COMPARISON OF BULLS, STEERS AND HEIFERS GIVEN THE SAME DIET AND SLAUGHTERED AT CONSTANT AGE

		GENDER		
		BULLS	STEERS	HEIFERS
Total dry matter intake (kg/day) (13 to 18 months of age)		9.2	8.8	8.3
Live-weight gain (kg/day)		1.30	1.10	0.96
Carcass gain (kg/day)		0.87	0.67	0.58
Live weight at slaughter (kg)		612	555	512
Carcass weight (kg)		353	310	284
Carcass fat classification	2	28%		
	3	70%	70%	40%
	4	2%	30%	60%
Conformation classification	E	5%		
	U	68%	20%	14%
	R	27%	68%	76%
	O		12%	10%
Carcass saleable meat content (%)		75	72	71
Fat trim (%)		7	10	11
Carcass lean content (%)		66	63	62
Carcass fat content (%)		19	23	24
Carcass bone content (%)		15	14	14

plant. Carcasses produced by bulls also had better conformation than those produced by steers, the average difference being 0.6 of a conformation class in the EU Classification Scheme. Similar results were obtained in two other experiments at Hillsborough which involved comparisons of bulls and steers (Steen, 1985b).

While the comparisons described above have related to bulls and steers slaughtered at the same age, alternatively, when steers have been reared on a grass-based system of production to 23 to 24 months of age, they have produced carcasses of similar weight to those produced by bulls slaughtered at under 18 months of age. Feed costs were similar for steers slaughtered at under 24 months and bulls at under 18 months, due to lower concentrate inputs to the steers. However, bulls had lower interest and overhead costs than steers due to the shorter production cycle.

Comparison of steers and heifers

During the finishing period steers consumed 6% more food and produced 16% more carcass weight gain than heifers. When they were slaughtered at the same age, steers produced carcasses which were 26 kg or 9% heavier than those produced by heifers. Steer carcasses were also slightly leaner than those of heifers, although there was no appreciable difference in the conformation of steer and heifer carcasses. To produce carcasses with the same fat content, heifers had to be slaughtered when they were 90 kg lighter than steers, and consequently produced carcasses which were 50 kg lighter than those of steers.

In a large scale study on 40 Northern Ireland farms (Ingram, 2001) the lifetime rate of carcass gain was also 9% higher for steers than for heifers, and in this case heifers were slaughtered 60 days earlier and produced 62 kg less carcass weight than steers.

Finishing young bulls from the suckler herd

Studies at both Hillsborough and Grange Research Centre have involved finishing continental cross bulls from the suckler herd on high quality grass silage supplemented with approximately 4 kg concentrates/head/day (Patterson and others, 1994 and 2000; Fallon and others, 2000). In the studies at Grange, spring-born calves were weaned at 8 to 9 months of age and fed for 240 days. Total feed inputs from weaning were 1.0 tonne of concentrates and 1.0 tonne of silage dry matter. The bulls were initially 300 kg live weight and gained 1.25 kg/day to reach a final live weight of 600 kg at about 16 months of age, and produced 350 kg carcasses.

In the studies at Hillsborough the bulls also produced 350 kg carcasses by about 16 months of age, but in this case the calves were born in May and were weaned at 6 months of age and consequently consumed more silage and slightly more concentrates than in the Grange studies. Continental cross bulls from the suckler herd produced very well conformed carcasses, those produced in the studies at Hillsborough being mainly E and U grades.

Continental-cross bulls from the suckler herd have also been finished at Grange at about 12 months of age, on a high-concentrate diet, with the only roughage source being a small amount of straw or hay. In this case the bulls consumed about 1.5 tonnes of concentrates and produced 325 kg carcasses (Fallon and others, 2000).

Although bulls are more efficient than steers and produce carcasses with better conformation, there is considerable concern amongst some of the major retailers regarding the eating quality of beef from bulls, and so it is important that producers make sure that they have a market outlet for bulls before starting to produce them. Bulls also require a higher standard of management than steers, both at farm level and prior to slaughter. Safety considerations are also of paramount importance in the production of young bulls for beef.

Bull beef production using Holstein bulls from dairy herds

Holstein calves from dairy herds have also been finished as bulls in studies at Grange and Hillsborough using high-concentrate diets. At Grange, they have been finished at 12 months of age, with a slaughter weight of 450 kg and a carcass weight of 240 kg. The bulls on this system consumed 1.8 tonnes of concentrates and 150 kg of straw or hay.

In the experiments at Hillsborough, Holstein bulls have been slaughtered at a series of live weights ranging from 300 to 550 kg (Kirkland and others, 2002 and 2003).

TABLE 26 THE EFFECT OF SLAUGHTER WEIGHT ON THE EFFICIENCY OF PRODUCING BEEF FROM HOLSTEIN BULL CALVES

	SLAUGHTER WEIGHT (KG)					
	300	350	400	450	500	550
Age at slaughter (months)	7.9	9.4	10.0	11.6	12.7	14.3
Concentrate intake (kg from 3 months)	795	1075	1288	1653	1955	2349
Carcass weight (kg)	153	179	210	243	271	296
Concentrates required/kg carcass gain from 3 months (kg)	7.9	8.5	8.2	8.7	8.9	9.6

Preliminary results from these experiments are summarised in Table 26. As live weight at slaughter increased, the animals required more feed per kg of carcass gain, especially at the highest slaughter weight. However feed costs per kg of gain are higher during the first three months of life due to the high cost of milk substitute relative to concentrates and the lower rate of gain at this stage. Overall profitability is also determined by the price of the calf and the value per kg of carcasses of various weights. If the cost of Holstein bull calves is taken as £30 and the total variable costs of rearing a calf to three months are assumed to be £60, then total variable costs per kg of carcass weight would be lower for bulls slaughtered between 400 and 500 kg live weight, than for animals slaughtered at lighter or heavier weights. As the beef processing industry has generally preferred carcasses of 240 to 260 kg rather than lighter carcasses, a slaughter weight of around 450 to 480 kg live weight may be most appropriate in terms of both minimising the costs of production and meeting market requirements. However this would obviously depend on future market requirements in terms of specifications for carcass weight and fatness.

SUMMARY OF THE MAIN POINTS ON PRODUCING BEEF FROM BULLS, STEERS AND HEIFERS

1. During the finishing period bulls which are well fed can grow about 20 to 30% faster than comparable steers, while in turn steers grow about 15% faster than heifers.
2. Bulls produce leaner, better conformed carcasses than steers and so require a higher level of feeding to ensure that they are well finished.
3. Although bulls are more efficient than steers and produce carcasses with better conformation, there has been considerable concern amongst some major retailers regarding the eating quality of beef from bulls, and so it is vital that producers make sure that they have a market for bulls before starting to produce them.

CHAPTER 9

HOUSING MANAGEMENT

The majority of beef cattle in Northern Ireland are housed in slatted accommodation during the winter, as this approach has the advantage of a lower labour requirement for the removal of manure than with solid floor accommodation, and no input of labour or materials for bedding. However, there is increasing public concern about the welfare of farm animals, and the issue of slatted accommodation for beef cattle has recently become of concern to some retailers and consumers in the U.K.

A comparison of floor types for finishing cattle

From a review of the available literature, Wierenga (1987) reported that housing bulls on fully slatted floors had a negative effect on their welfare. However, the majority of the information related to intensive Continental European systems, in which bulls were reared intensively on fully slatted floors from 3 to 6 months of age until slaughter. This approach is in contrast to that normally practiced in Northern Ireland, in which cattle are at pasture during the summer, and are housed only during the winter.

Consequently two experiments were carried out at Hillsborough to examine the effects of housing cattle on fully slatted floors, on solid floored, straw bedded accommodation or on slatted floors in which the slats were covered with rubber strips or rubber mats (Lowe and others, 2000 and 2001a). The bullocks were on the experiment from about 440 to 600 kg live weight. Those on slats had 3.0 m2 of floor space/animal, while those on straw bedding had 5.3 m2 per animal, and were kept well bedded with 5.5 kg straw/head/day. The cattle on the different floor types had similar performance, carcass gains being 0.67 kg/day for those on slats and 0.69

TABLE 27 THE EFFECT OF FLOOR TYPE ON THE PERFORMANCE AND WELFARE OF BEEF CATTLE

	FLOOR TYPE			
	SLATS	RUBBER MATS*	RUBBER STRIPS*	STRAW BEDDED
Feed intake (kg/day)	9.0	9.1	9.2	8.9
Live-weight gain (kg/day)	1.06	1.14	1.13	1.12
Dressing percentage	55.2	54.7	54.9	54.9
Carcass gain (kg/day)	0.67	0.69	0.69	0.69
EU fat classification	3.6	3.6	3.6	3.5
Carcass composition				
Lean (%)	63.2	63.8	63.9	63.5
Fat (%)	21.3	20.8	20.5	20.8
Bone (%)	14.8	14.8	14.8	14.8
Relative incidence of behaviours				
Aggressive behaviour	100	133	70	122
Repetitive behaviour	100	103	103	116
Percent of time spent lying down	62	63	62	61
Number of times the cattle got up and down/day	8	10	11	14

* The rubber mats and rubber strips were laid on conventional slats

kg/day for those on straw bedding and rubber covered slats. Floor type did not affect carcass composition or meat quality as shown in Table 27.

In an experiment at Knockaloe Farm, Isle of Man (Personal communication from D.N. Peck) finishing cattle housed on a fully slatted floor grew faster than those housed on straw bedding (1.12 versus 1.02 kg live-weight gain/day).

In the studies at Hillsborough the cattle on slats were dirtier than those on straw in one experiment, but not in the other, while cattle on mats were the dirtiest in both experiments.

A higher incidence of aggressive or repetitive behaviours amongst cattle is an indicator of poorer animal welfare. In these experiments floor type had no significant effects on the incidence of aggressive or repetitive behaviours. However, cattle on straw lay down and got up more often than those on mats/strips which in turn lay down and got up more often than those on uncovered slats. This would indicate that cattle on slats experienced difficulty getting up and down. There was no clinical lameness in any of the cattle on any of the floor types. However cattle housed on slats had more solar and white line lesions on their hind feet than those on straw, while cattle on straw had more heel lesions on their fore and hind feet, than those on slats. When given a choice, cattle preferred to lie on straw rather than strips/mats, and on strips/mats rather than on slats (Lowe and others, 2001b).

Implications of this research for the beef industry

All the floors used in these experiments were of a high quality, in that the slats were of good quality and the straw-bedded floors, were bedded every day with 5-6 kg of straw/animal. However supplies of straw are very limited and expensive in Northern Ireland, and it has been calculated that the amount of straw produced in the Province would provide bedding for only about 20% of the cattle at present. Consequently if large numbers of cattle were housed on straw bedded floors in practice, they may well be bedded with less straw than the recommended amounts used in these experiments. The welfare of cattle in poorly managed, straw-bedded accommodation could be poor and the cattle may well be dirtier than those in well managed slatted units.

The absence of any significant effect of floor type on animal performance, carcass composition or meat quality in these experiments would indicate that there is likely to be little financial return to producers, if they changed from good quality, well managed slatted accommodation to straw bedded accommodation during the winter for cattle which had previously been at pasture during the summer, unless meat processors and/or retailers offer a premium price for cattle off straw or refuse to purchase cattle from slatted units. However, it is important to emphasize that the results of these experiments should not be applied to systems of production in which cattle are housed all year (e.g. indoor bull beef systems), as continuously housed cattle may well be affected differently by slatted floors than those which have been at pasture over the summer and housed only during the winter.

It is also important that the results of these experiments are not applied to situations in which the condition of slatted floors, and/or the management of the cattle on slatted floors, are such that animal performance is depressed below that which would be obtained if the cattle were housed on more "comfortable" floors. Also the quality and management of rubber covered slats could also influence animal performance. In two experiments at Grange Research Centre (Linehan, 2000) the live-weight gain of cattle housed on conventional slats was approximately 20% lower than that of cattle housed on slats covered with rubber strips. These results would indicate that under certain management conditions the performance of cattle housed on conventional slats can be depressed below that of cattle housed on more "comfortable" floors.

The absence of any increase in the incidence of aggressive or repetitive behaviours in the experiments at Hillsborough when cattle were housed on slats rather than on straw, would indicate that slats are not detrimental in terms of this measure of animal welfare under the conditions of these experiments. However cattle on slats lay down and got up less frequently than those on rubber-covered slats or straw. This would indicate that animals had difficulty getting up and/or down on the hard and slippery slatted floor, while bedding created a softer floor and the necessary foothold and security for them to get up and down more easily. In addition when offered a choice, cattle preferred straw rather than any of the other floors, and preferred rubber covered slats rather than conventional slats.

In summary, straw bedded accommodation is preferable from an animal welfare perspective. However in areas such as Northern Ireland where the supply of straw is very limited, covering slats with strips or mats would improve the ease of cattle getting up and down on slats and lying comfort, and so would offer a compromise in terms of animal welfare. However, a major disadvantage of rubber mats was that the cattle on these were the dirtiest, while those on rubber strips were as clean as those on conventional slats or straw.

Therefore the welfare of beef cattle could be improved by covering slats with rubber strips because cattle preferred slats covered with rubber, and cattle on rubber covered slats got up and down more often. Cattle on rubber-covered slats also had fewer lesions on their hind feet than those on slats and fewer heel erosions on their fore and hind feet than those on straw. However slats covered with rubber strips are a relatively new phenomenon and more information is needed on how durable they will be over a prolonged period. Furthermore the potential value of slats covered with rubber strips to the Northern Ireland beef industry will depend on how they would be viewed from an animal welfare perspective by the major food retailers and by consumers.

Outwintering pads

A further, alternative approach to wintering beef cattle has recently been pioneered in Scotland (Lowman and Hill, 2002) and evaluated at Grange Research Centre (Hickey and French, 2000). This has involved accommodating cattle on "outwintering pads" over the winter months. These were constructed on a drained site by covering sub-soil and stones with 100 kg of "buttchip" (i.e. slices of bark and wood)/m2. Finishing cattle were accommodated on the open (i.e. unroofed) pads at stocking densities of 6, 12 or 18 m2/animal or in a slatted floor shed with 3 m2 of floor space per animal.

Finishing cattle kept on the outdoor pads consumed 4% more food and gained 12% more carcass weight than those kept in the slatted shed. The stocking density on the outdoor pads did not affect animal performance.

There was no indication from the initial results that keeping finishing cattle outdoors on well managed pads over the winter detrimentally affected their welfare.

Although the work at Grange has involved finishing cattle, out-wintering pads are not recommended for finishing cattle in Scotland (Lowman and Hill, 2002) because the cattle are likely to become dirty during wet winter months. Consequently in Scotland they are only recommended for dry suckler cows and store cattle. From economic and animal welfare perspectives, out-wintering pads offer an alternative approach to conventional sheds for over-wintering cattle, which has a much lower initial capital cost but a higher maintenance cost in subsequent years. However in Northern Ireland there is currently considerable concern about the risk of environmental pollution from out-wintering pads and the consequences for farmers if a pollution incidence occurs during the winter when the cattle are on a pad and there is no alternative accommodation available for them.

Producing clean cattle

Research has recently been undertaken at Hillsborough and Grange Research Centre to examine the factors which affect the cleanliness of finishing beef cattle. In the Hillsborough study the dirtiness of the cattle in 164 finishing units on 133 commercial farms across Northern Ireland was examined (O'Hagan and Steen, 2000), while at Grange a smaller study was carried out on commercial farms combined with experiments at the Research Centre (Fallon and Prendiville, 2000).

In the studies undertaken at Hillsborough cattle housed in sheds with poor ventilation and with a high proportion of the pen floor as solid concrete were significantly dirtier than those in well ventilated sheds and those with little solid concrete floor area in slatted accommodation.

Contrary to much conventional belief, low stocking densities in slatted accommodation did not result in dirtier cattle. In fact there was a tendency for cattle kept at high stocking densities to be dirtier than those kept at lower stocking densities. These findings are supported by those from Grange, which showed that cattle were dirtier when over-stocked in slatted pens.

In the Hillsborough study, cattle given high inputs of concentrates were also dirtier than those given moderate concentrate inputs. Cattle given wet feeds such as molasses and potatoes were dirtier than those given only dry concentrates and cattle given dry silage (dry matter content above 30%) and first cut silage were cleaner than those given wet silage or third cut silage made in late summer or autumn.

In the studies at Grange, taking cattle off pasture prior to slaughter and housing them over-night in straw-bedded accommodation to avoid heavy rainfall resulted in cleaner cattle, while feeding hay to cattle at pasture for one to two days before slaughter did not affect the cleanliness of the cattle at the abattoir. Frequent handling of cattle prior to slaughter and transporting them in very wet conditions also made them dirtier. In the Hillsborough study, clipping the animals' flanks and bellies at housing improved their cleanliness, but if the clipped cattle did get dirty later in the winter, it was extremely difficult to get them cleaned again prior to slaughter because the dung on the short hair was very close to the skin.

SUMMARY OF THE MAIN POINTS ON HOUSING MANAGEMENT

1. The performance of cattle in straw bedded accommodation has been little better than that of cattle in well managed slatted accommodation.
2. Management of cattle on slats can reduce performance compared to the performance of cattle on more “comfortable” floors.
3. Some aspects of the welfare of cattle on slats have been as good as those of cattle on straw, but in other respects slats have been inferior in terms of welfare.
4, Covering slats with rubber has improved assessments of the welfare of cattle housed on slats.
5. Over-wintering cattle on “outdoor wintering pads” has produced very satisfactory performance but there is concern about the environmental implications of this approach to over-wintering cattle.
6. Contrary to conventional recommendations, using high stocking rates for cattle on slats has not produced cleaner cattle.
7. Diet can have a major effect on the dirtiness of finished cattle.

SECTION 2
LAMB PRODUCTION

CHAPTER 10

REDUCING THE COSTS OF LAMB PRODUCTION THROUGH THE USE OF HIGH QUALITY BREEDING STOCK

The first step in maximising the efficiency and profitability of lamb production is to have good breeding stock, of the most appropriate breed type for the conditions under which they are being kept. Different breeds of sheep have specific characteristics which make them more or less suitable to use as breeding stock under different conditions and management systems.

A key feature of the Northern Ireland sheep industry is what is termed the stratified crossbreeding programme, which involves crossing hill breeds such as Scottish Blackface ewes with Border or Blue Faced Leicester rams to produce Greyface or Mule ewes for breeding in the lowlands, or crossing Cheviot ewes with Suffolk rams to produce Suffolk cross Cheviot ewes for breeding in the lowlands. The fact that these crossbred ewes are then normally crossed with a third breed or ram, such as Texel or Suffolk, maximises the benefits of hybrid vigour in the production of finished lambs.

As discussed earlier in relation to cattle, hybrid vigour is the phenomenon which results in the performance of a crossbred animal being better than the average performance of its two purebred parents. Hybrid vigour has been found to have a very major effect on the weight of lambs produced per ewe put to the ram in a wide range of sheep production systems with crosses between three breeds being superior to crosses between two breeds (Vesely and Peters, 1972; Rastogi and others, 1982). Crossbred ewes produce more lambs per ewe put to the ram than purebred ewes, mainly through better fertility, and lambs produced by crossbred ewes are more vigorous with lower mortality rates and higher growth rates than lambs produced by purebred ewes (Vesely and others, 1972; Hohenboken and Cochran, 1976; McGuirk and others, 1978; Dawson and others, 2002c).

In a recent study at Hillsborough, Texel cross Rouge de l'Ouest ewes produced 8% more lambs per ewe put to the ram than the average number of lambs produced by pure Rouge and pure Texel ewes. Lambs produced by the crossbred ewes had a 50% lower mortality rate and a higher growth rate than lambs produced by the purebred ewes. **Consequently, overall, the weight of lambs weaned per ewe put to the ram was over 50% higher for the crossbred lambs produced by crossbred ewes than for purebred lambs. These findings again emphasize the critical importance of maintaining a well organised crossbreeding programme within lowland sheep flocks, and avoiding a situation in which one breed becomes dominant within the genetics of the flock.**

Dominance of one breed within the genetics of a flock of ewes can easily occur when the same breed of terminal sire is used year after year and ewe lamb replacements are retained from within the home flock. However research findings have shown that this is likely to result in a substantial reduction in the output of weaned lambs per ewe put to the ram. This emphasizes the importance of maintaining a well organised crossbreeding policy, because the magnitude of the hybrid vigour expressed varies depending on which combination of breeds are used in the cross (Rastogi and others, 1982). For example crossing two white-faced breeds is unlikely to produce as much hybrid vigour as crossing a white-faced and a black-faced breed.

The effect of ewe and ram breeds on output from hill flocks

An extensive study has recently been carried out on six hill farms across Northern Ireland to

examine the effects of crossing each of two breeds of ewes with three ram breeds on the number and quality of lambs weaned and finished per ewe put to the ram (Carson and others, 2001a and 2001b). Scottish Blackface ewes were mated with Scottish Blackface, Blue-faced Leicester and Texel rams, while Wicklow Cheviot ewes were mated with Cheviot, Suffolk and Texel rams. The results of this major study are summarised in Table 28. Cheviot ewes produced heavier lambs at birth than Blackface ewes, but with the exception that lambs sired by Blackface rams were lighter, ram breed had little effect on lamb birth weight.

Neither ewe nor ram breed had any major effect on the number of lambs born/ewe, lamb mortality or the number of lambs weaned/ewe put to the ram. Pure Blackface lambs had lower growth rates than the other five breed crosses, which had similar growth rates. The lambs were slaughtered when they reached carcass fat classification 3. The purebred Blackface lambs required a six week longer finishing period to reach fat class 3 than the other

TABLE 28 THE EFFECT OF EWE AND RAM BREEDS ON OUTPUT FROM HILL FLOCKS (CARSON AND OTHERS, 2001A AND 2001B)

	BREEDS OF RAMS CROSSED WITH SCOTTISH BLACKFACE EWES BREEDS OF RAMS CROSSED WITH CHEVIOT EWES					
	BLACKFACE	LEICESTER	TEXEL	CHEVIOT	SUFFOLK	TEXEL
Percentage of barren ewes	21	15	15	17	16	15
Number of lambs born/ewe lambed	1.54	1.55	1.52	1.49	1.57	1.55
Birth weight of lambs (kg)	4.1	4.4	4.5	4.8	4.9	4.8
Number of lambs weaned per ewe lambed	1.32	1.30	1.28	1.24	1.24	1.36
Number of lambs weaned per ewe put to the ram	1.12	1.17	1.14	1.10	1.11	1.20
Percentage of ewes which lambed without assistance	90	84	76	85	81	84
Live-weight gain of lambs - birth to weaning (kg/day)	0.18	0.20	0.20	0.20	0.21	0.21
Output of weaned lambs 38(kg/ewe put to the ram)	29	36	35	34	36	
Live-weight gain during finishing (kg/day)	0.14	0.21	0.20	0.19	0.22	0.20
Age at slaughter (weeks)	42	37	36	37	35	35
Carcass weight (kg)	17.8	19.1	19.1	19.2	19.1	19.4
Fat classification	3.0	3.0	3.0	3.0	3.0	3.0
Conformation classification*	2.4	2.4	2.8	2.7	2.7	3.1

* Based on E = 5, U = 4, R = 3, O = 2 and P = 1

five breed crosses. Despite this longer finishing period, the pure Blackface lambs still produced carcasses which were 1.4 kg lighter than the average carcass weight for the other five breed crosses, which produced carcasses of similar weight. Cheviot ewes produced lambs which had a third of a conformation class better conformation than lambs produced by Blackface ewes. Similarly, lambs sired by Texel rams had better conformation (0.4 of a class) than lambs sired by rams of the other breeds.

Overall the results of this study on commercial farms across Northern Ireland suggest that a change from Scottish Blackface to Wicklow Cheviot ewes on hill farms would have little effect on the number of lambs weaned per ewe put to the ram, but would produce faster growing, purebred lambs. These lambs would require about 5 weeks less feeding to produce a fat class 3 carcass. They would also produce heavier carcasses with better conformation than those produced by Blackface lambs. Cheviot ewes tend to be slightly larger than Blackface ewes and so would have a slightly higher food requirement but this would be more than offset by the increase in lamb output. This may become a much more important factor post mid term review of the CAP, particularly if the number of sheep on the hills is reduced.

The effect of ewe breed on output from lowland flocks

The breed structure of hill flocks is important not only in terms of its effect on the number and quality of the finished lambs of the hill breeds which are produced, but also on the quality of the crossbred ewe lambs as lowland ewes and hence their market value as ewe lambs. Consequently ewe lambs from the study described above were brought down to five lowland farms to examine their potential as lowland breeding ewes (Dawson and others, 2002a and 2002b).

The four ewe breed crosses which were studied were:

- Blueface Leicester cross Blackface (Mule)
- Texel cross Blackface
- Suffolk cross Cheviot
- Texel cross Cheviot

Ewes of each of these crosses were mated with either Suffolk or Texel rams. The results of this study are summarised in Table 29. The number of lambs produced per ewe was lower than normal for lowland flocks because 38% of lambings were by ewe lambs, 39% by two year olds and only 23% by three year old ewes and there were no older ewes in the study.

The Leicester cross Blackface (Mule) ewes produced and reared about 20% more lambs than the other three breed crosses which produced a similar number of lambs. Lambs were slaughtered when they reached fat class 3. Lambs produced by the Texel cross ewes had slightly lower growth rates than those produced by the traditional Mule and Suffolk/Cheviot ewes, and so required one to

TABLE 29 THE EFFECT OF EWE AND RAM BREEDS ON LAMB OUTPUT ON LOWLAND FARMS (DAWSON AND OTHERS, 2002A AND 2002B)

	BREED CROSS OF EWES			
	LEICESTER X BLACKFACE	TEXEL X B LACKFACE	SUFFOLK X CHEVIOT	TEXEL X CHEVIOT
Percentage of barren ewes	9	11	15	11
Number of lambs born/ewe lambed	1.73	1.47	1.46	1.41
Birth weight of lambs (kg)	5.0	4.7	4.9	4.9
Number of lambs weaned per ewe lambed	1.40	1.20	1.21	1.18
Number of lambs weaned per ewe put to the ram	1.28	1.09	1.07	1.07
Live-weight gain of lambs – birth to weaning (kg/day)	0.26	0.25	0.26	0.25
Output of weaned lamb (kg/ewe put to the ram)	42	36	34	34
Live-weight gain of lambs – birth to slaughter (kg/day)	0.20	0.19	0.20	0.19
Age at slaughter (weeks)	27	28	27	29
Carcass weight (kg)	19.1	18.9	19.1	19.4
Fat classification	3.0	3.0	3.0	3.0
Conformation classification*	2.8	3.2	3.0	3.2

* E = 5, U = 4, R = 3, O = 2 and P = 1

two weeks longer to produce carcasses of the same weight as those produced by the traditional breeds of ewes. However lambs produced by Texel cross ewes had better conformation than those produced by the traditional ewe breeds, especially compared to those produced by the mule ewes.

The results of this study on Northern Ireland farms are in line with the results of earlier experiments in Great Britain and the West of Ireland. In these studies undertaken by Cameron and others (1983), Mann and others (1984) and Hanrahan (1994), Blue-faced Leicester cross Blackface (Mule) ewes produced about 0.1 more lambs per ewe than Border Leicester cross Blackface (Greyface) ewes. Also, the Greyface ewes produced about 0.1 more lambs/ewe than Texel cross Blackface ewes. Therefore the results obtained on Northern Ireland farms are in close agreement with the results of these earlier studies in that the Mule ewes produced 0.3 more lambs/ewe lambed, and reared 0.2 more lambs/ewe put to the ram than the Texel cross Blackface ewes. In the study of Hanrahan (1994), Cheviot cross Blackface and pure Blackface ewes were even less prolific than the Texel cross Blackface ewes (i.e. 0.15 to 0.22 fewer lambs reared/ewe put to the ram).

It is concluded that, even though the Mule ewes produced lambs with poorer conformation than those produced by ewes of the other three breed crosses, the value of this was more than offset by the fact that the Mule ewes produced about 20% more lambs than the other ewes. Consequently the Mule ewes were more profitable than the other breed crosses.

In a further study at Hillsborough, Johnston and others (1999) compared Greyface and Suffolk Cheviot ewes. In this study the number of lambs born and weaned per ewe put to the ram was similar for the two breed types. However half of the ewes of each breed cross were mated with Suffolk rams and half with Dutch Texel rams. Ewes which were mated with the Suffolk rams produced about 20% more lambs than those which were with the small Dutch Texel rams. This was partly due to the fact that a large proportion (17%) of the Greyface and Suffolk Cheviot ewes which were with the Texel rams did not lamb. However when purebred Dutch Texel ewes were mated with the small Dutch Texel rams, a high proportion (95%) of the ewes lambed. These findings suggest that the small Dutch strain of Texel rams used in this study were not suitable for mating with large crossbred ewes such as Greyface and Suffolk Cheviot.

Two further experiments have been carried out at Hillsborough to evaluate a range of ewe breeds for producing finished lambs in the lowlands. In the first experiment, Carson and others (1999a and 1999b) compared purebred Dutch Texel ewes, Greyface, Texel cross Greyface and purebred Rouge de l'Ouest ewes, while in the second experiment Dawson and others (2002c and 2003) compared pure Dutch Texel, Texel cross Rouge and purebred Rouge ewes. In both experiments all of the breeds of ewes were mated with Texel rams as terminal sires. The results for the purebred Texel and Rouge ewes have little application to commercial lamb production, given the low prolificacy and high incidence of lambing difficulties with purebred Texel ewes and the high lamb mortality rate with the purebred Rouge ewes. However, the fact that both of these pure breeds were included in both experiments has enabled the data for these two breeds to be used as standards, so that the data for the two experiments can be combined to provide a direct comparison between the crossbred genotypes. The combined results for the two experiments are summarised in Table 30.

The number of lambs born/ewe lambed varied from 1.88 for the purebred Texel ewes to 2.42 for the purebred Rouge ewes. Texel ewes had a high incidence of lambing difficulty while the Rouge ewes had the lowest incidence and the crossbred ewes were intermediate. Nevertheless, there was a very high mortality rate of over 40% amongst the lambs produced by the purebred Rouge ewes, and consequently the number of lambs weaned/ewe was lowest for the Rouge ewes. Among the crossbred ewes, Greyface ewes had the lowest number of lambs weaned/ewe, while the Texel x Rouge ewes had the highest number and the Texel x Greyface were intermediate.

The very high mortality rate in the lambs produced by the Rouge ewes may have been related to the large number of lambs produced by these ewes, although in other studies even higher prolificacy rates have not been associated with such high rates of lamb mortality (e.g.

TABLE 30 THE EFFECTS OF EWE BREED ON LAMB PRODUCTION IN A LOWLAND FLOCK

	BREEDS OF EWE CROSSED WITH TEXEL RAMS				
	TEXEL	GREYFACE	TEXEL X GREYFACE	TEXEL X ROUGE	ROUGE DE L'OUEST
Number of lambs born per ewe lambed	1.88	2.00	2.09	2.20	2.42
Lamb birth weight (kg)	4.5	5.1	4.8	4.3	4.3
Number of lambs born dead or died until weaning/ewe	0.35	0.51	0.29	0.20	0.98
Number of lambs weaned per ewe lambed	1.53	1.49	1.79	2.00	1.43
Live-weight gain of lambs – birth to slaughter (kg/day)	0.18	0.20	0.19	0.20	0.21
Slaughter weight at 30 weeks of age (kg)	42.5	47.2	45.4	46.1	48.0
Dressing percentage	48.0	45.8	47.8	47.1	46.6
Carcass weight (kg)	20.4	21.6	21.7	21.7	22.4
Fat classification	3.2	3.3	3.4	3.3	3.4
Conformation classification*	4.5	3.4	4.2	4.3	4.0
Weight of carcass produced/ewe	31.2	32.2	38.8	43.4	32.0

* Conformation E = 5, U = 4, R = 3, O = 2 and P = 1

Maund and others, 1980; Gallo and Davies, 1988). For example, Maund and others (1980) reported data for a flock of over 1,000 ewes, which included about 12% lambings by ewe lambs and the mature ewes produced over 2.4 lambs/ewe. Lamb mortality rate before birth, including mummified foetuses, and up to six weeks after birth, was 10% for ewes producing 2.0 lambs/ewe lambed compared to 22% for ewes producing 2.1 lambs/ewe in the studies at Hillsborough. Mortality rate was also less than 17% for ewes producing over 2.4 lambs/ewe compared to over 40% mortality in lambs produced by ewes with the same lambing rate in the experiments at Hillsborough.

Also in the studies at Hillsborough, the ewes with triplet lambs produced a high proportion of very small lambs and the mortality rate was very high among these small lambs. This problem may have been reduced by providing a higher level of feeding during late pregnancy for ewes carrying triplets, as this may have increased lamb birth rate. Alternatively, the management of the ewes in these studies may not have been appropriate for very prolific ewes.

In the studies at Hillsborough, lamb growth rates varied from 0.18 kg/day for pure Texel lambs to 0.21 kg/day for lambs produced by Rouge ewes. Consequently when the lambs were slaughtered at a constant age of 30 weeks, slaughter weight varied from 42.5 kg for Texel lambs to 48 kg for Texel x Rouge lambs. However the Texel lambs had a higher killing-out percentage so that the range in carcass weights was only 2 kg, and the three crossbred ewe types produced lambs of similar carcass weight.

There was also little difference between the five lamb breed crosses in terms of carcass fat classification, but there was a large difference in carcass conformation between breeds. The conformation of the lambs produced by the Greyface ewes was over one class lower than that of the pure Texel lambs, while the conformation of the lambs produced by the Texel cross Greyface and Texel cross Rouge ewes was almost as good as that of the pure Texel lambs.

Ewe breed type had a major effect on the weight of lamb carcass produced per ewe, in that Texel cross Greyface ewes produced 20% more carcass weight than Greyface ewes, while Texel cross Rouge ewes produced 35% more carcass weight/ewe than Greyface ewes. As well as this, the conformation of the carcasses produced by the Texel cross ewes was almost one class better than that of the lambs produced by the Greyface ewes.

The results of these experiments indicate that a change from traditional Greyface ewes to Texel cross Greyface or Texel cross Rouge ewes could produce a major increase in the output of lamb carcass weight from lowland sheep flocks, and at the same time result in a substantial improvement in carcass quality. However, the results of these experiments should be treated with caution, as those for each of the crossbred ewe types relate to only one experiment, and the results of different experiments can vary depending on the constraints and management within each experiment.

There were also a number of factors within these experiments which merit consideration. Firstly, small Dutch Texel rams were used in these experiments, and an unusually high proportion (18%) of the large breeds of ewes did not produce lambs. This was likely to have been a result of the small rams used, rather than due to the ewes, as a high proportion of these ewes (95%) produced lambs when they were with larger rams. Consequently the number of lambs produced per ewe put to the ram has not been presented, as differences in the proportions of the ewes which did not lamb between ewe breeds were likely to have been due to the rams used, rather than to the ewes themselves.

Secondly, there is no obvious explanation for the unusually high mortality rate among the lambs produced by the Greyface ewes in this study.

Thirdly, the number of lambs produced by the Greyface cross Texel ewes was greater than that produced by either the Texel or Greyface ewes. While hybrid vigour has generally improved fertility in ewes (i.e. reduced the proportion of barren ewes) and reduced mortality rates and increased growth rate in lambs, it has not usually affected the number of lambs produced per ewe lambing. Consequently the number of lambs produced by crossbred ewes per ewe lambed is usually close to the average for the two parent breeds, as was the case for the Texel cross Rouge ewes in the studies at Hillsborough. Therefore the high lambing rate for the Texel cross Greyface ewes, in comparison to the purebred Texels and the Greyface ewes is unusual.

Despite these limitations, the results of this major study do indicate that a change from Greyface to Texel cross Greyface or Texel cross Rouge ewes, could produce a major increase in lamb output and the quality of lamb carcasses from lowland flocks and so a cautious examination of the potential of these breed crosses at farm level is merited.

The effect of terminal sire breed on lamb production from lowland flocks

Data provided by the Meat and Livestock Commission in Great Britain has shown that at least 10 different breeds of rams are used as terminal sires in lowland sheep flocks in the UK. However, of these, Suffolk and Texel rams have been most widely used and so several experiments have been undertaken to evaluate Suffolk and Texel rams as terminal sires. Data produced in eight experiments undertaken by More O'Ferrall and Timon (1977a and 1977b) in Ireland, Latif and Owen (1979 and 1980), Wolf and others (1980) and Kempster and others (1987) in Great Britain and by Johnston and others (1999) at Hillsborough are summarised in Table 31.

In each experiment the lambs sired by the Suffolk and Texel rams were produced by the same breeds of ewes. In total, the eight comparisons involved almost 4,000 lambs, so these data represent a very strong comparison of the two sire breeds. Lambs sired by Suffolk rams had a 7% higher live-weight gain from birth to slaughter than lambs sired by Texel rams. However the difference between the two breeds varied from zero to 11%, depending on which strains of the two breeds were used. For example, Johnston and others (1999) used small Dutch Texel rams and so in this case the Texel cross lambs grew 11% slower than the Suffolk sired lambs.

On average over the eight comparisons, Texel sired lambs were one week older and one kg lighter at slaughter than

TABLE 31 COMPARISONS OF SUFFOLK AND TEXEL RAMS AS TERMINAL SIRES FOR LOWLAND LAMB PRODUCTION. (AVERAGE RESULTS OF EIGHT EXPERIMENTS)

	SIRE BREED	
	SUFFOLK	TEXEL
Live-weight gain, birth to slaughter (g/day)	243	227
Live weight at slaughter (kg)	42	41
Age at slaughter (weeks)	22	23
Dressing percentage	45.2	46.2
Carcass weight (kg)	18.9	18.9
Carcass lean content (%)	57.5	60.8
Carcass fat content (%)	25.3	22.2
Carcass bone content (%)	16.5	16.4

TABLE 32 THE EFFECT OF SIRE BREED ON THE CARCASS COMPOSITION OF LOWLAND FINISHED LAMBS

SIRE BREED	CARCASS WEIGHT (KG)	LEAN CONTENT (%)	FAT CONTENT (%)	BONE CONTENT (%)
Texel	18.4	59.2	23.4	16.2
Suffolk	18.5	56.3	26.1	16.8
Oxford Down	18.5	55.8	26.1	17.1
Hampshire Down	17.4	55.3	26.5	16.4
Dorset Down	17.9	55.0	27.8	16.4
Ile de France	17.7	55.9	26.1	16.9

the Suffolk sired lambs. However the Texel lambs had a slightly higher dressing percentage and so average carcass weight was the same for the two breeds. However, the Texel sired lambs consistently produced carcasses with a higher lean content and a lower fat content than the Suffolk sired lambs, the average difference over the eight experiments being three percentage units higher lean content and three percentage units lower fat content for the Texel sired lambs.

The four comparisons carried out by More O'Ferrall and Timon (1977), Wolf and others (1980) and Kempster and others (1987) also involved a comparison of several other breeds of rams as well as Suffolks and Texels. The results for this more limited comparison of a wider range of breeds are summarised in Table 32.

Carcass weights were reasonably constant, although carcass weights for lambs sired by Suffolk, Texel and Oxford Down rams were slightly higher than for lambs sired by Hampshire Down, Dorset Down and Ile de France rams. Lambs sired by Suffolk, Oxford Down, Hampshire Down and Ile de France rams produced carcasses with similar lean and fat contents while lambs produced by Dorset down rams were slightly fatter than those produced by the rams of the other breeds.

The striking feature of these comparisons was the fact that again the Texel sired lambs consistently produced leaner carcasses than those produced by lambs sired by rams of the other breeds. On average over all the comparisons, the carcasses of the Texel sired lambs contained over three percentage units more lean and three percentage units less fat than the carcasses of lambs sired by rams of the other five breeds. In the few experiments in which carcass conformation was assessed, Texel sired lambs had similar or slightly better conformation than lambs sired by rams of the other breeds. The greatest difference in carcass conformation, in favour of the Texel sired lambs, was in the study of Johnston and others (1999) in which small rams of the Dutch strain of the Texel breed were used.

There would appear to have been few comparisons of Texel rams with rams of the other Continental breeds as terminal sires in lowland flocks. One experiment undertaken by Cameron and Drury (1985) involved a comparison of Texel and Charollais rams as terminal sires. In this case the lean and fat contents of the Charollais sired lambs were intermediate between those of the lambs sired by Texel rams and rams of the English breeds. Two of the experiments at Hillsborough involved a comparison of Texel and Rouge de l'Ouest rams crossed with Greyface or Texel cross Rouge ewes (Carson and others, 1999a; Dawson and others, 2002c). In these experiments lambs sired by rams of the two breeds produced carcasses with similar lean and fat contents, but the Texel sired lambs had slightly better conformation.

There is also limited information to suggest that Texel sired lambs may have lower mortality rates than Suffolk sired lambs (Leymaster and Jenkins, 1993; Johnston and others, 1999) and may be less susceptible to some internal parasites than Suffolk sired lambs (Johnston and others, 1999), while in studies at Hillsborough, Texel sired lambs had lower mortality rates than Rouge sired lambs (Carson and others, 1999a; Dawson and others, 2002c).

Overall, the results of extensive research on the effects of using different breeds of rams as terminal sires in lowland lamb production have shown that the use of Texel rams has produced lambs with superior carcass quality. There is more limited information to indicate that mortality rates may be lower in Texel sired lambs than in lambs sired by Suffolk or Rouge de l'Ouest rams. Texel lambs required one week longer than Suffolk sired lambs to produce carcasses of the same weight as the Suffolk cross lambs. However, particularly for the majority of lambs which are finished at pasture, the cost of a week's extra feeding would be small in comparison to the benefits in carcass quality and possibly also a lower lamb mortality rate. Lambs produced by the small Dutch Texel rams used in the studies at Hillsborough would appear to have had slightly better conformation than those produced by the larger strains of Texel rams. However in view of their lower growth rate and the fact that an unusually high proportion of the larger ewes that were with the Dutch Texel rams were not in lamb, rams of the larger strains of the Texel breed are likely to be more appropriate as terminal sires, especially with larger ewes.

SUMMARY OF THE MAIN POINTS FROM THE REVIEW OF RESEARCH ON PRODUCING HIGH QUALITY BREEDING STOCK

1. In hill flocks, Cheviot ewes had similar prolificacy to Blackface ewes, but Cheviots produced better quality lambs.
2. Crossing Blackface or Cheviot ewes with Texel rather than Blue-faced Leicester or Suffolk rams did not affect lamb survival, but improved the quality of the lamb carcasses produced.
3. Even though Texel x Blackface and Texel x Cheviot ewes produced better quality lambs than Blue-faced Leicester cross Blackface (Mule) ewes, Mule ewes were more profitable because they were more prolific.
4. Hybrid vigour, which is the superiority of a crossbred animal over the average of its two purebred parents, has been shown to produce major benefits in terms of lambing rate per ewe put to the ram (mainly through better fertility), reduced lamb mortality rate and better lamb growth rates. It is therefore vitally important that a structured crossbreeding policy is maintained within Northern Ireland sheep flocks.
5. There is an urgent need to examine the potential of other hardy breeds of sheep, such as Lleyn, Cheviot, Swaledale and Beulah and their crosses as breeding ewes for hill areas of Northern Ireland.
6. Mule ewes have been more prolific than Greyface ewes which in turn have been more prolific than Texel cross Blackface ewes.
7. In a limited number of experiments, Texel x Greyface, and in particular, Texel cross Rouge de l'Ouest ewes, were more prolific than Greyface ewes. Texel cross Rouge and Texel cross Greyface ewes also produced lambs with better quality carcasses than those produced by Greyface ewes.
8. Mule and Greyface ewes have good prolificacy but their use as lowland ewes has limited the quality of the lamb carcasses produced. Research findings to date suggest that the use of Texel terminal sires in hill flocks would greatly improve the quality of the finished lambs produced in these flocks. As this would reduce the availability of prolific ewe lambs from the hill flocks, the feasibility of producing crossbred ewes in the lowlands, such as Texel cross Rouge ewes, should be examined. The limited amount of information available to date indicates that this could combine the hardiness and superior carcass quality of the Texel with the prolificacy and carcass quality of the Rouge.
9. This has potential to improve both the prolificacy of lowland ewes and the quality of the lamb carcasses produced compared to the use of Greyface ewes.
10. Extensive research has shown that Texel rams are superior to rams of a wide range of other breeds in terms of the carcass quality of their progeny.
11. The use of small rams of the Dutch strain of Texel resulted in an unusually high proportion of large ewes not being in lamb. Consequently the use of the larger strains of Texel rams as terminal sires is likely to be preferable, especially with larger ewes.

CHAPTER 11

FEEDING AND MANAGEMENT OF BREEDING EWES FROM BEFORE MATING UNTIL LAMBING TO OPTIMISE REPRODUCTIVE PERFORMANCE

Feeding of breeding ewes should be centred around having the ewes in optimum body condition at various stages of the annual production cycle as discussed for suckler cows in Chapter 2. The three most critical times in the annual production cycle of ewes are before and after mating, during late pregnancy and during early lactation.

Feeding before and after mating

Early research in Great Britain clearly demonstrated the importance of the body condition of ewes at mating on fertility and lambing percentage. In several studies, ewes which were in poor body condition at mating had a much lower ovulation rate and lambing percentage than ewes which were in optimum body condition at mating. For example, Rhind and others (1984) found that Scottish Blackface ewes which had a body condition score of 2.75 to 3.0, on a five point scale, at mating conceived 1.55 lambs/ewe compared to only 0.9 lambs/ewe for ewes with a condition score of 1.5 to 1.75 at mating. Similarly, Gunn and others (1972) found that ewes which had a condition score of 3.0 prior to and at mating had a lambing rate of 1.55 lambs/ewe compared to only 0.48 lambs/ewe for ewes with a condition score of 1.5 for 3 weeks prior to, and at mating, as shown in Table 33.

The results of several experiments have also shown that as well as being in the correct body condition at mating, ewes also conceive more lambs when they have been fed to gain weight and condition during the last two to four weeks before mating. For example, Gunn and Doney (1975) found that Blackface ewes which had a body condition score of 3.0, five weeks before mating and were poorly fed for the next five weeks until mating, so that they had a condition score of only 2.5 at mating, produced only 0.81 lambs/ewe. On the other hand, ewes which had a condition score of 2.0, five weeks before mating and were well fed so that their body condition improved to a score of 2.5 at mating, had 1.32 lambs/ewe.

Thus when both groups of ewes had the same condition score at mating, the ewes which had been gaining condition for the five weeks before mating had over 60% more lambs than the ewes which had been losing condition before mating. However, ewes which had been in condition score 3.0, five weeks before mating and were fed to maintain condition until mating so that they still had a condition score of 3.0 at mating, had the same number of lambs as those which had a condition score of 2.0, five weeks before mating, increasing to a score of 2.5 at mating.

Gunn and others (1987) obtained similar results with both Cheviot and Beulah Speckled Face ewes. In this study, ewes which were gaining weight for the last four weeks before mating had much higher ovulation rates and conceived about 50% more lambs than ewes which were losing weight during the last four weeks before mating, even when the ewes were in reasonably good condition. Similarly, Gunn and Maxwell (1989) found that Greyface ewes which were gaining live weight at the time of mating produced 24% more lambs than ewes which were losing live weight at mating time, as shown in Table 34. Also Merrell (1990) found that ewes which were put onto good grazing five weeks before the rams were introduced, but had the sward grazed down and were losing substantial

TABLE 33 THE EFFECT OF EWE BODY CONDITION AT MATING ON LAMBING RATE IN SCOTTISH BLACKFACE EWES

	BODY CONDITION SCORE AT MATING	
	1.5	3.0
Average number of embryos per ewe 26 days after mating	0.56	1.57
Proportion of barren ewes (%)	52	6
Lambing rate (lambs/ewe)	0.48	1.55

(Gunn and others, 1972)

TABLE 34 THE EFFECT OF LIVE-WEIGHT CHANGE AROUND THE TIME OF MATING ON LAMBING RATE IN GREYFACE EWES (GUNN AND MAXWELL, 1989)

	LIVE-WEIGHT CHANGE AT MATING		
	GAINING WEIGHT	MAINTAINING WEIGHT	LOSING WEIGHT
Number of ewes	114	339	221
Live weight at mating (kg)	70	68	67
Average number of lambs born/ewe	1.96	1.78	1.58

live weight during the mating period had a lambing rate of 1.37 lambs/ewe. This compared to 1.68 lambs/ewe for ewes which had a similar body condition score at mating, but were put onto good grazing only two weeks before the rams were introduced and so were almost maintaining weight during the mating period.

Other studies have shown that when ewes were in poor body condition five weeks before mating (i.e. a condition score of less than 2) and were then on a high plane of nutrition for the five week period until mating, the number of lambs conceived was still much lower than the number conceived by ewes which had been in good body condition (i.e. condition score 3.0) during the whole of the pre-mating period (Gunn and Doney, 1975).

Extensive data from recent studies undertaken on commercial farms across Northern Ireland through the Agricultural Research Institute at Hillsborough have confirmed the earlier findings, i.e. lambing percentage is severely reduced when ewes are in poor condition at mating or are losing condition prior to mating (Carson and others, 2001b).

Taken together, these research findings indicate that lambing percentage is influenced both by the body condition of ewes at the time of mating and also whether they have been gaining or losing condition prior to and around the time of mating. **They indicate that to maximise lambing percentage, ewes should have a condition score of around 3, one month before the rams are to be introduced, and that they should then be fed to ensure that this body condition is at least maintained or that there is a slight increase in body condition from then until the ewes have been mated.**

The findings also indicate that extremes of, or changes in, feeding level should be avoided at this critical stage in the annual production cycle. This means that if a proportion of ewes in a flock are in poor body condition, 2 to 3 months before the rams are to be introduced, they should be separated from the rest of the flock at this stage and given preferential treatment so that their body condition is adjusted to as close to 3 as possible, well in advance of mating, if lambing percentage is to be maximised.

Robinson (1983a) and McKelvey and Robinson (1986) reviewed research findings on the effects of nutrition during early pregnancy on the survival of embryos in ewes and hence on lambing percentage. Robinson (1983a) presented a substantial amount of research information which would indicate that embryo mortality may be increased, and hence lambing percentage decreased, by either underfeeding or by a high plane of nutrition during the first month of pregnancy. McKelvey and Robinson (1986) reached similar conclusions and emphasized the need to avoid a high level of feeding during the first month of pregnancy, as this has been found to reduce embryo survival at this stage.

On the basis of these findings it seems prudent to manage ewes to maintain body condition during the first month of pregnancy, and as far as possible avoid either low or high levels of feeding which results in either a significant loss or gain in body condition at this stage, as these may reduce embryo survival. Maximising embryo survival is likely to be most effectively achieved by allowing ewes access to a large area of relatively short, clean grass. This ensures that ewes can maintain a reasonable level of feeding, while at the same time keeping fit, because they have to roam over a relatively large area to gather their feed. Providing ewes with a small area of long grass so that they can gather their feed in a short time and then lie for prolonged periods is likely to be a much less satisfactory approach to maximising lambing percentage (Robinson, 1995).

Feeding ewe lambs

It is important that ewe lambs which are to be kept for breeding have an adequate level of feeding during the first 12 months of their life, and especially during the first 2 to 3 months, as underfeeding at this stage can have a detrimental effect on the number of lambs that they will produce over several years of their productive life. For example, Gunn (1983) reported the results of an experiment in which Scottish Blackface ewe lambs were maintained on a high or low plane of nutrition for the first year of life and were fed similarly thereafter. The high and low planes of nutrition produced ewes which were 39 and 27 kg live weight respectively at 12 months. Over five successive years, from 2 to 6 years old, the ewes which had been reared on the higher plane of nutrition produced 1.7 lambs/ewe/year on average, compared to 1.4 lambs/ewe/year for those reared on the low plane of nutrition. Gunn (1983) also reported other findings which would indicate that the first 2 to 3 months of life is probably the period when underfeeding is likely to have the greatest long-term effects on lamb production in later life. These results indicate that underfeeding of ewe lambs in early life can have long-term persistent effects on lambing percentage in adult life.

Feeding during mid-pregnancy

From the end of the first month of pregnancy to the end of the third month, the growth of the foetus in absolute terms is small and so places little additional demand on the ewe for nutrients. In contrast, by day 90 of pregnancy the placenta has completed its growth process (Robinson, 1983b). This results in the placenta being more sensitive than the foetus to underfeeding in mid-pregnancy. Robinson (1983b) reviewed the research findings on the effects of feeding during the second and third months of pregnancy. From this he found that if ewes lost more than 5% of their body weight (i.e. more than 0.5 units of body condition) during the second and third months of pregnancy the size of the placenta at 90 days of pregnancy was reduced, and consequently the birth weight of the lambs may be reduced (Robinson, 1990). However Robinson (1983a) found that ewes can compensate to some extent for underfeeding during mid pregnancy if they are well fed during late pregnancy. Nevertheless, this compensation is likely to be only partial, and has been found to depend on the body condition of the ewe at the end of the first month of gestation, the number of lambs that she is carrying and whether she is a young or a mature ewe.

Consequently, the optimum level of feeding for ewes in mid pregnancy is likely to depend on their age and body condition at the beginning of this period (Gunn and others, 1986; Robinson, 1990). Research findings would indicate that when ewes are in good body condition (i.e. a body condition score above 3.0) at the end of the first month of gestation lamb production is likely to be increased by feeding ewes to lose up to 0.5 of a body condition score during the second and third months of gestation (Robinson, 1983b; Gunn and others, 1986). For example, Gunn and others (1986) found that when Greyface ewes had a body condition score of 3.5 fifty days after the rams were introduced, and were fed to either maintain weight during mid pregnancy or lose 2 to 5 kg of live weight, the ewes which lost live weight during mid pregnancy had a lambing rate of 1.9 lambs/ewe compared to 1.6 lambs/ewe for those which maintained live weight during mid pregnancy.

When ewes are in good body condition (i.e. condition score 3.0) a mild degree of under-nutrition resulting in a steady loss of up to 0.5 of a unit of body condition during the second and third months of gestation is unlikely to reduce the growth of the placenta and consequently is unlikely to reduce the birth weight of the lambs. Indeed some results would suggest that for ewes which are in good body condition, mild under-nutrition during mid pregnancy may actually enhance placental growth and subsequent lamb birth weight in ewes which are well fed during late pregnancy (Robinson, 1990). On the other hand more severe underfeeding which results in the loss of more than 0.5 of a unit of body condition, inevitably leads to a reduction in placental size at 90 days of gestation and this can result in lower lamb birth weights (Robinson, 1990). However, young ewes and ewes which are in poorer body condition are more vulnerable to under-nutrition during mid pregnancy (Robinson, 1990) and so it is prudent to ensure that these ewes are fed to maintain body condition during mid pregnancy. Robinson (1990) has suggested that these interactions between the age and body condition of ewes and feeding level during mid pregnancy on lamb birth weight should not be seen as an unnecessary complication which can be ignored. Rather they should be viewed as valuable observations for use in developing management strategies which improve the overall productivity of the flock by accommodating the diverse needs of ewes within the flock which are in different body condition and are either mature or are young and still growing.

This view is further supported by observations made by Apolant and Chestnutt (1982), who experienced a problem with pregnancy toxaemia in ewes in late pregnancy and suggested that this may have been related to excessive weight gain by the ewes in mid pregnancy. Having ewes overfat during late pregnancy may reduce feed intake at this stage, as fat ewes have been found to eat less food than ewes in lower body condition (Cowan and others, 1980; Treacher, 1983). This in turn would increase the risk of pregnancy toxaemia in late pregnancy.

Feeding ewes during late pregnancy

The increase in the weight of the lamb foetus during the last eight weeks of gestation is normally equivalent to 85% of the birth weight of the lamb, while the increase during the last four weeks of gestation is normally equivalent to 50% of the birth weight of the lamb (Robinson, 1983a). Consequently there is a steep increase in the energy and protein requirements of ewes during the last seven weeks of gestation. However, even though energy requirements increase greatly during the last few weeks of pregnancy, the ewe's capacity to consume bulky feeds actually declines at this stage (Appleton, 1987), which can result in a severe energy deficit unless sufficient concentrates are fed to increase energy intake to near energy requirements.

The results of an extensive series of experiments undertaken at Hillsborough by Apolant and Chestnutt (1985) and Wilkinson and Chestnutt (1988) have shown that lowland crossbred ewes of 70 to 75 kg body weight can consume around 1.1 to 1.3 kg of good quality, precision-chopped silage dry matter during the last two months of pregnancy. This type of silage supplemented with an average concentrate input of about 0.20 kg/ewe/day, or a total intake of around 10 kg/ewe, has been sufficient to meet, or almost meet the energy requirements of twin bearing ewes during the last seven weeks of gestation, so that there was little or no weight loss between mid pregnancy and post-lambing.

However the intake of silages made with a flail forage harvester was about 25% lower than the intake of precision-chopped silage in the experiments at Hillsborough as shown in Table 35. Consequently, when

TABLE 35 A COMPARISON OF PRECISION-CHOPPED SILAGE AND SILAGE WITH A LONG PARTICLE LENGTH FOR EWES IN LATE GESTATION (APOLANT AND CHESTNUTT, 1985)

	SILAGE TYPE	
	PRECISION-CHOPPED	LONG PARTICLE LENGTH
Concentrate intake (kg/ewe in last seven weeks of gestation)	12	12
Average concentrate intake (kg/ewe/day)	0.25	0.25
Silage dry matter intake (kg/ewe/day)	1.1	0.8
Live-weight change, 10 weeks before lambing to after lambing (kg/ewe)	+1.4	-4.8
Change in body condition score, 7 weeks before lambing to after lambing	0.2	-0.6
Lamb birth weight (kg)	5.3	5.0

TABLE 36 THE EFFECT OF THE DIGESTIBILITY OF GRASS SILAGE ON THE PERFORMANCE OF GREYFACE EWES DURING LATE PREGNANCY (APOLANT AND CHESTNUTT, 1985; BLACK AND CHESTNUTT, 1989)

	SILAGE D-VALUE (%)	
	63	74
Silage dry matter intake (kg/ewe/day)	1.1	1.2
Concentrate intake (kg/ewe in last seven weeks of gestation)	20	20
Average concentrate intake (kg/ewe/day)	0.40	0.40
Live-weight change, mid-pregnancy to after lambing (kg)	-5.3	+3.4
Change in body condition score, mid-pregnancy to after lambing	-0.6	+0.2
Lamb birth weight (kg)	5.2	5.4

poorer quality silages with a longer particle length have been fed during late pregnancy, silage dry matter intakes have been only around 0.7 to 0.9 kg/ewe/day, and consequently a total concentrate input of about 30 to 35 kg/ewe or 0.6 to 0.7 kg/ewe/day during the last seven weeks of gestation has been required to meet or almost meet the average energy requirements of twin bearing ewes, and so result in only slight weight loss between mid pregnancy and post-lambing (Apolant and Chestnutt, 1985; Wilkinson and Chestnutt, 1988). Although the intake by ewes of clamp silages made with flail forage harvesters has been 25% lower than the intake of precision-chopped silages, sheep given higher dry matter silage made in round bales have had similar dry matter intakes and performance as those given either precision-chopped (Anderson, 1985) or double-chopped silages (Grennan, 2000).

The digestibility of grass silage offered to ewes in late gestation also has a major effect on their performance as shown in Table 36. Increasing the D-value of grass silage offered during late pregnancy, from 63 to 74% resulted in Greyface ewes gaining live weight and body condition between mid pregnancy and after lambing, instead of losing 5 kg of body weight and 0.6 units of body condition.

In a further experiment at Hillsborough, Black and Chestnutt (1989) offered Greyface ewes silages with D-values of 69 and 74% during mid- and late-gestation. In this study the ewes given the higher digestibility silage were 12 kg heavier before lambing and 10 kg heavier after lambing than those given the lower digestibility silage.

On the basis of the responses to offering additional concentrates to ewes during late pregnancy in the six experiments undertaken by Apolant and Chestnutt (1985) and Wilkinson and Chestnutt (1988), increasing the average D-value of silage offered to the ewes in the experiments undertaken by Apolant and Chestnutt (1985) and Black and Chestnutt (1989) from 66 to 74% on average, would have enabled the concentrate intake during the last seven weeks of gestation to be reduced by 25 to 30 kg per ewe without affecting the body weight of the ewes or the birth weight of the lambs.

Feeding poorly preserved silages with high pH and high contents of ammonia and butyric acid and with high levels of soil contamination can lead to listeriosis (Appleton, 1987). This disease can cause abortion, septicaemia or encephalitis from which there is no cure (Appleton, 1987). Consequently, it is vitally important that silage used for feeding sheep is well made with a good fermentation and is free of moulds. Wilting the grass prior to ensiling or using an effective additive can improve silage fermentation. High quality grass with a

D-value of at least 70% should be used and it should be precision chopped to increase intake and thereby reduce the requirement for purchased concentrates.

More recently, Carson and others (2003) examined the effects of a range of concentrate inputs for twin bearing ewes which were at pasture during the last six weeks of gestation. When ewes had an adequate supply of grass during February and March, an input of 0.5 kg of concentrates/ewe/day or a total intake of 21 kg/ewe during the last six weeks of gestation was sufficient to prevent a loss in body condition of the ewes during this period. In this experiment, ewes which had adequate grass and were given no concentrates lost only 0.2 units of body condition during the last six weeks of gestation which would be an acceptable loss of condition in ewes which were in good body condition at the beginning of the period. On the other hand, ewes which had only a limited amount of grass available required 0.75 to 1.0 kg of concentrates/ewe/day during the last six weeks of gestation to prevent a loss of body condition during this period. The results of this experiment clearly show the potential of grass as a feed for pregnant ewes during the late winter. However providing an adequate supply of grass for ewes during the late winter requires effective grassland management during the autumn and winter to ensure that pasture is available for the ewes at this time of the year.

The effect of the pattern of concentrate feeding during late pregnancy

Although the energy requirements of ewes increase steeply during the last two months of pregnancy, offering ewes a constant input of concentrates/day in addition to silage offered ad libitum over the last seven weeks of pregnancy has given as good results as offering a lower input of concentrates seven weeks before lambing and increasing concentrate intake gradually to a high level during the last week before lambing. Indeed flat-rate feeding of concentrates in addition to roughage offered ad libitum has been satisfactory even for very prolific breeds of ewes (Robinson, 1990).

Flat-rate feeding of concentrates to ewes offered forage ad libitum during the last seven weeks of gestation avoids the very high level of concentrate feeding during the last week of gestation which is associated with an ascending pattern of concentrate intake during late pregnancy. This high concentrate intake before lambing can easily lead to a rapid increase in acidity in the rumen as a result of the fermentation of starch in the concentrates, which in turn can cause poor digestion of fibre, poor appetite and pregnancy toxaemia. Also as ewes approach lambing, flat-rate feeding causes a transition from the energy intake of the ewe being above her requirement for energy to intake being below her requirement. This enables the ewe to gradually adapt to a deficit of some nutrients, such as calcium, which is likely to occur during early lactation, and therefore is better introduced in late pregnancy when demand in relative terms is lower than during early lactation (Robinson, 1990).

Protein supplementation during late pregnancy

If the energy intake of ewes is substantially below their requirement for energy during late pregnancy, they must mobilise body fat as a source of energy. In this situation, increasing the supply of protein to the ewes, especially protein which is not degraded in the rumen, can improve the efficiency with which the mobilised body fat is utilized as an energy source and reduce the susceptibility of the ewe to pregnancy toxaemia (Robinson, 1990). It can also increase lamb birth weight and improve the production of colostrum by the ewe (Annett and Carson, 2003). However in a series of experiments at Hillsborough, Wilkinson and Chestnutt (1988) found that when additional protein of low degradability in the form of fish meal was given to twin-bearing ewes in addition to grass silage and concentrates containing 12 to 17% protein, there was no improvement in performance. This was despite the fact that the energy intake of some of the ewes was substantially below requirements. Similarly, Stone and Appleton (1986) offered ewes silage ad libitum and a supplement of up to 0.6 kg barley/ewe/day or a mixture of barley and fish meal for 10 weeks before lambing. Including fish meal in the supplement did not improve lamb birth weight or the performance of the ewes or the lambs. Also in a recent study at Hillsborough, Dawson and others (1999b) fed twin-bearing lowland crossbred ewes a restricted intake of silage supplemented with concentrates with or without protected soyabean meal or fish meal. Although the ewes were underfed, the inclusion of either protected soyabean meal or fish meal did not affect the performance of the ewes, lamb birth weight, the quantity or quality of the ewe's colostrum or the subsequent performance of the lambs.

However in another recent experiment at Hillsborough, Annett and Carson (2003) offered triplet-bearing ewes a restricted intake of grass supplemented with concentrates containing protein of high or low degradability in the rumen during the last six weeks of gestation. Energy intakes were below requirements so that the ewes were losing body condition. In this experiment offering protein with a lower degradability in the rumen did not affect the live weight or body condition of the ewes but it did reduce post-natal mortality in the lambs, presumably through its effect on colostrum production.

These results would indicate that when triplet-bearing ewes are underfed in late pregnancy there is likely to be a benefit from including in the diet a protein source of low degradability such as "protected" soyabean meal, linseed meal or maize gluten meal (also known as prairie meal). It should be noted that maize gluten meal is a very different feed from maize gluten feed which is usually widely available in Northern Ireland but which contains protein with a very high degradability in the rumen.

The effect of shearing ewes at housing in mid pregnancy

The effects of shearing lowland crossbred ewes at housing in mid-pregnancy has been examined in several experiments. For example, in a series of experiments undertaken at Hillsborough by Black and Chestnutt (1989) and in Great Britain by Morgan and Broadbent (1980), Maund (1980) and Vipond and others (1987), shearing ewes in winter when they were housed in mid-pregnancy increased feed intake and lamb birth weights. The magnitude of the increase in lamb birth weight appeared to depend on the diet of the ewes. When ewes were given diets of grass silage supplemented with concentrates the increase in lamb birth weight as a result of shearing was around 15%, while the increase in birth weight as a result of shearing was only about 8% in ewes given hay-based diets. Mortality rates have also generally been lower in lambs born to shorn ewes than in those born to unshorn ewes. This has been associated with the higher birth weight of lambs produced by shorn ewes. However in one experiment undertaken by Morgan and Broadbent (1980) mortality was higher in lambs produced by sheared ewes, probably as a result of over-sized lambs. This emphasizes the importance of avoiding over-feeding of shorn ewes during late pregnancy.

Other husbandry benefits which result from shearing ewes in the winter, when they are housed, include the ability to assess the body condition of the ewes much more easily, the ease of observing signs of udder development and imminent lambing, improved access of the newborn lambs to the teats, and a reduced risk of lambs being overlaid by the ewe. Other benefits of shearing in winter include a reduction in housing costs and after being turned out to pasture shorn ewes are more likely to seek shelter during bad weather and so reduce the risk of the lambs developing hypothermia (Vipond and others, 1987).

The effects of housing or keeping breeding ewes at pasture during late gestation and while they are lambing

Labour costs represent a major proportion of the total costs of lamb production. It has been estimated that labour inputs to sheep enterprises are about 4 to 8 man hours/ewe/year in Northern Ireland. Consequently a study was undertaken at the Research Institute at Hillsborough, and on five commercial farms across Northern Ireland, to examine the effects of housing ewes in late pregnancy and during lambing, or keeping them outside, on labour requirements and on ewe and lamb performance (Carson and others, 2002). Ewes of four breed crosses on each farm were either housed during late pregnancy or were removed from the farm grassland in mid pregnancy and fed silage or root crops. Three to six weeks before lambing, the ewes which were to be lambed outside were returned to the grazing area for lambing. During the lambing period ewes were not removed from this lambing area until 12 to 48 hours after lambing.

Research in New Zealand has indicated that ewes and lambs should not be disturbed during the first 2 to 6 hours after lambing, because this is the period when the maternal bonding between the ewe and her lambs develops (Smith and Knight, 1990). As shown in Table 37, the birth weight of the lambs born outside was slightly higher than that of the lambs born indoors. This may have been a result of the housed ewes not having been shorn, as housing unshorn ewes has been found to reduce the

TABLE 37 THE EFFECTS OF LAMBING BREEDING EWES INDOORS OR AT PASTURE ON LABOUR INPUTS AND EWE AND LAMB PERFORMANCE (CARSON AND OTHERS, 2002)

	LAMBING SYSTEM	
	INDOORS	AT PASTURE
Labour input around the time of lambing (minutes/ewe)	14	8
Number of lambs born/ewe	1.79	1.77
Lamb birth weight (kg)	5.0	5.2
Number of lambs born dead/ewe	0.10	0.11
Number of lambs died – birth to weaning/ewe	0.10	0.12
Number of lambs weaned/ewe	1.59	1.54
LIVE-WEIGHT GAIN OF LAMBS (KG/DAY)		
Birth to 6 weeks	0.29	0.31
Birth to weaning	0.27	0.27
Weaned lamb output (kg/ewe)	57	56

birth weight of lambs compared to those produced by housed shorn ewes as discussed earlier. Mortality rates were similar in lambs produced by the ewes which lambed indoors and those which lambed at pasture.

This finding is in agreement with earlier results from a study undertaken in England by Maund (1980) in which mortality rates were similar in lambs produced by housed unshorn ewes and out-wintered ewes. However in this study, mortality rates were lower in lambs produced by sheared housed ewes than in lambs produced by either unshorn housed ewes or out-wintered ewes. The lambs which were born at pasture had a slightly higher growth rate to six weeks of age than those which were born indoors. Again this may have been because the ewes which were housed during late pregnancy were not sheared, as lambs produced by sheared, housed ewes have had slightly higher growth rates during early life than those produced by unshorn, housed ewes in previous studies (Morgan and Broadbent, 1980). Overall, the output of weaned lamb/ewe was similar for ewes which lambed indoors and those which lambed at pasture in the Northern Ireland study (Carson and others, 2002), while labour requirements around the time of lambing were 6 minutes/ewe less for the ewes which were lambed at pasture, which would represent about a 2% reduction in total annual labour requirements for Northern Ireland sheep flocks.

However the relative labour requirements and costs for indoor and outdoor lambing systems are likely to vary greatly from farm to farm depending on the availability of various resources on the farm. These include the requirement for reasonably dry land with shelter for outdoor lambing and the proximity of this land to the f arm dwelling and the availability and quality of buildings on the farm for indoor lambing and whether or not they can be used for other purposes during the remainder of the year. The prevalence of foxes and other predators and the impact of these on lamb mortality would also affect the suitability of an individual farm for an outdoor lambing system. The higher lamb birth rates and lower lamb mortality which have been recorded for lambs produced by sheared, housed ewes compared to unsheared housed ewes used in this study is a further factor which needs to be taken into account when assessing the advantages and disadvantages of lambing ewes indoors or at pasture.

SUMMARY OF THE MAIN POINTS ON FEEDING BREEDING EWES TO OPTIMISE REPRODUCTIVE PERFORMANCE

1. To maximise the number of lambs produced per ewe put to the ram, ewes should be in good condition (condition score of around 3.0) at least one month before the rams are introduced, and they should be at least maintaining or have a slight increase in condition during the month before mating and until after they have been mated.

2. Even if ewes are in good body condition before mating a loss of body condition during the mating period can reduce lambing rate. Similarly, even if ewes are on a high plane of nutrition immediately before and during the mating period, having them in poor body condition before mating can reduce lambing rate.

3. Having ewes on either a very high or very low plane of nutrition during and for about one month after mating, or a sudden change in the level of feeding at this stage can reduce lambing rate.

4. Providing ewes with a large area of relatively clean short grass during and after mating, so that they can maintain a reasonable level of feeding, but must keep fit by having to roam over a relatively large area to gather their feed, is likely to produce better results than providing them with a small area of long grass.

5. Providing ewes are in good body condition after mating, it has generally been beneficial to feed them to achieve a slight loss of body condition during the second and third months of pregnancy.

6. As this period corresponds to the late autumn/early winter period for March lambing ewes, it means that the ewes can be used to graze swards off to a low sward height at this stage, which is also beneficial to the over-wintering of the swards.

7. Over-feeding ewes in mid-pregnancy resulting in overfat ewes in late pregnancy, is likely to reduce feed intake at this stage which can increase the risk of pregnancy toxaemia.

8. Silage fed to ewes during late pregnancy should be well made with a good fermentation and should be free of moulds.

9. To minimise feed costs during late gestation, silage should be made from good quality grass with a D-value of at least 70% and should be precision-chopped.

10. When good quality, precision-chopped silage has been available ad libitum a concentrate intake of 0.2 kg/day or a total of 10 kg/ewe over the last seven weeks of gestation has provided an adequate level of feeding for twin-bearing ewes. With poorer quality silage a concentrate input of 0.7 kg/day or 35 kg/ewe during the last seven weeks of gestation has been required to achieve the same level of feeding.

11. Shearing pregnant ewes at the time of housing has reduced heat stress during late pregnancy, increased lamb birth weight and reduced lamb mortality rate providing the ewes were not over-fed during late pregnancy.

CHAPTER 12

FEEDING BREEDING EWES AFTER LAMBING AND GRASSLAND MANAGEMENT FOR SHEEP

To achieve high growth rates in twin lambs, lowland crossbred ewes need to produce 2.5 to 3.0 kg of milk/ewe/day during the first month of lactation (Robinson and others, 1974; Gibb and Treacher, 1982). This requires an intake of about 30 MJ of metabolisable energy and 400 g of protein or 2.5 to 3.0 kg of dry matter of a good quality diet/ewe/day. As most ewes in the British Isles are at grass from lambing or soon after lambing, research information on feeding ewes during lactation relates mainly to ewes at pasture and there seems to be little information on feeding early lambing ewes on diets of conserved forage and concentrates during early lactation.

In a series of experiments at Hillsborough, Greyface ewes given good quality silage and 0.8 kg of concentrates/ewe/day consumed 1.5 kg of silage dry matter/ewe/day and produced around 2.5 kg of milk/ewe/day which sustained live-weight gains of about 0.25 kg/day in twin lambs (Apolant and Chestnutt, 1985). However when ewes were given lower quality silage supplemented with 0.8 kg of concentrates/ewe/day, ewes consumed only one kg of silage dry matter/day and lamb growth rates were poor at 0.15 to 0.20 kg/day. In a series of eight experiments undertaken in Great Britain by Orr and Treacher (1994), ewes rearing twin lambs were offered precision-chopped silage or hay of medium to low digestibility ad libitum and supplemented with 0.3, 0.65 or 1.0 kg of concentrates/ewe/day during the first month of lactation. Increasing concentrate intake from 0.3 to 1.0 kg/ewe/day increased the live-weight gains of the lambs from 0.22 to 0.27 kg/day and reduced the rate at which the ewes lost live weight and body condition as shown in Table 38. On the basis of the results of these experiments, a concentrate input of approximately 1 kg/ewe/day is likely to be required to achieve a good growth rate of around 0.3 kg liveweight gain/day in twin lambs suckling lowland ewes given good quality, precision-chopped silage ad libitum. When medium quality silage or hay is used, a concentrate input of 1.5 kg/day is likely to be required to sustain the same level of performance, but if only poor quality silage or hay is available then a concentrate input of up to 2 kg/ewe/day may be required to sustain a high growth rate in the lambs.

However, in situations in which poor quality forage is being used and hence high concentrate inputs are needed, it is vitally important that the concentrates have a high proportion of ingredients with a low starch content. High intakes of cereals with a high starch content can cause a rapid increase in acidity in the rumen, as a result of excessive fermentation of starch in the concentrates, which in turn can cause poor digestion of fibre in the diet and loss of appetite.

While the data discussed above relate to crossbred ewes such as Greyface, higher feed intakes and growth rates in lambs can be achieved with more prolific breeds of ewes with a high potential for milk production. For example, Gallo and Davies (1988) carried out an experiment at Liverpool University with Cambridge and Cambridge cross Suffolk ewes. These were very prolific ewes in that 44% of them produced two lambs each, 28% produced three lambs and 28% produced four lambs each. The smallest lambs were removed from their mothers at four days of age so that half of the ewes reared twins and the other half reared triplets. These prolific high yielding ewes had very large appetites, in that they were offered either 2.4 or 3.3 kg of concentrates/ewe/day during the first five weeks of lactation, and they still consumed 1.5 to 2.0 kg

TABLE 38 THE EFFECT OF LEVEL OF CONCENTRATE FEEDING DURING THE FIRST MONTH OF LACTATION ON THE PERFORMANCE OF EWES AND THEIR TWIN LAMBS WHEN THEY WERE OFFERED MEDIUM QUALITY SILAGE OR HAY (ORR AND TREACHER, 1994)

	CONCENTRATE INPUT (KG/EWE/DAY)		
	0.30	0.65	1.00
Live-weight change in ewes during first month (kg/day)	-0.34	-0.23	-0.21
Body condition score change in ewes during first month (kg/day)	-0.53	-0.46	-0.42
Live-weight gain of lambs during first month (kg/day)	0.22	0.24	0.27

TABLE 39 THE EFFECT OF CONCENTRATE FEED LEVEL AND THE NUMBER OF LAMBS REARED PER EWE ON THE PERFORMANCE OF CAMBRIDGE AND SUFFOLK CROSS CAMBRIDGE EWES AND THEIR LAMBS (GALLO AND DAVIES, 1988)

	CONCENTRATE INPUT (KG/EWE/DAY)	
	2.4	3.3
Hay intake (kg/ewe/day)	2.0	1.5
Total dry matter intake (kg/ewe/day)	3.8	4.1
Milk yield (kg/ewe/day)	4.0	4.1
Change in ewe body condition score during first 5 weeks of lactation	-0.7	-0.5
LIVE-WEIGHT GAIN OF LAMBS (KG/DAY)		
First 5 weeks	0.32	0.33
Birth to slaughter	0.30	0.31
	NUMBER OF LAMBS REARED/EWE	
	TWO	THREE
Concentrate intake (kg/ewe/day)	2.8	2.8
Total dry matter intake (kg/ewe/day)	3.9	3.9
Milk yield (kg/ewe/day)	3.9	4.2
Change in ewe body condition score during first 5 weeks of lactation	-0.5	-0.7
LIVE-WEIGHT GAIN OF LAMBS (KG/DAY)		
First 5 weeks	0.37	0.30
Birth to slaughter	0.33	0.29

of hay/ewe/day as shown in Table 39. The ewes given the higher input of concentrates lost less body condition during the first five weeks of lactation, but feeding extra concentrates had little effect on milk yield or the growth rate of the lambs. Ewes rearing triplets had the same feed intake as ewes rearing twins, but they produced slightly more milk and lost more body condition than those rearing twins. The growth rates of the lambs were exceptionally high, being 0.37 kg live-weight gain/day for the twin lambs and 0.30 kg/day for the triplets to five weeks of age.

The ewes and lambs were turned out to pasture five weeks after lambing and the lambs continued to have high growth rates, so that the twin lambs had a live-weight gain of 0.33 kg/day from birth to slaughter, while those reared on the ewes as triplets had a live-weight gain of 0.29 kg/day from birth to slaughter. The results of this experiment demonstrate the high food intakes, high milk yields and high growth rates of lambs, even when reared as triplets on the ewe, which can be achieved with this type of high yielding, highly prolific ewe.

However the high concentrate intakes which are required for highly prolific ewes, or for less prolific ewes if the quality of the silage or hay available is poor, can greatly increase the costs of producing finished lambs. Consequently it is usually desirable to provide clean grazing for ewes and lambs as soon as possible after lambing.

Extensive research carried out in Great Britain has shown that typical lowland ewes can consume around 3 kg of grass dry matter/day when an adequate supply of spring grass is available. For example, Milne and others (1981) recorded live-weight gains of 0.33 kg/day to six weeks of age for twin lambs suckling Greyface ewes which grazed a perennial ryegrass sward in a Scottish upland situation without concentrate supplementation. In an extensive series of experiments undertaken at the Grassland Research Institute in Berkshire involving mainly Border Leicester cross Cheviot ewes, Orr and others (1990) recorded a live-weight gain of 0.30 kg/day from birth to weaning at 15 to 17 weeks of age, for twin lambs grazing a perennial ryegrass/white clover sward with their mothers. Gibb and Treacher (1982), Young and others (1980) and Penning and others (1988) recorded live-weight gains of 0.27 to 0.28 kg/day from birth to 4 to 8 weeks of age, and 0.26 kg/day from birth to 12 weeks of age, for twin lambs suckling their mothers and grazing perennial ryegrass swards.

In a two year experiment at Hillsborough, Chestnutt (1990) recorded live-weight gains of 0.28 to 0.31 kg/day until weaning for lambs suckling their mothers on either perennial ryegrass or ryegrass/white clover swards when they had a liberal allowance of pasture, but a live-weight gain of only 0.21 kg/day when the ewes and lambs grazed a short sward. In this case, two-thirds of the lambs were twins and one third were singles.

However in an earlier study at the Grassland Research Institute, Gibb and Treacher (1980) recorded a live-weight gain of only 0.21 kg/day for twin lambs from birth to 16 weeks of age, even though they had an adequate supply of grass.

The effects of offering ewes rearing twin lambs supplementary concentrates either during early spring when the availability of grass has been limited, or later in the season when the ewes have had an adequate supply of grass, has been examined in several experiments. However both Young and others (1980) and Milne and others (1981) recorded very little response in the growth rate of twin lambs (i.e. 2 to 8% increase) when the ewes were given cereal-based concentrates during early lactation, even when there was a fairly severely restricted supply of spring grass available. On the other hand, Penning and others (1988) recorded live-weight gains of 0.25, 0.26 and 0.29 kg/day for twin lambs during the first six weeks, when ewes were grazing a ryegrass sward with no supplement, or were given approximately 0.8 kg of concentrates/day containing either 5 or 25% protein respectively. These authors also obtained similar responses for ewes given concentrates containing either soyabean meal or fish meal.

Treacher (1990) reviewed research findings on the effects of offering concentrates to ewes during early lactation in both lowland and upland situations. These research findings indicated that supplementation was not justified in lowland flocks unless the swards were very short, with a sward surface height of less than 3 cm. Even then, while there may well be benefits in the short term, the effects on lamb weight at weaning may be negligible. For March lambing lowland flocks, the period from lambing until sward height reaches 3 to 4 cm is generally short for pastures which have not been grazed since they were grazed down to a height of 3 cm in the early winter.

Treacher (1990) concluded that there may be some value in concentrate supplementation to reduce losses of body condition in the ewes during early lactation, but that under lowland conditions, fat reserves can usually be replaced easily after the lambs have been weaned. However if the swards used after lambing have been grazed during the winter, a longer period of concentrate feeding is likely to be required before sward height reaches 3 to 4 cm. In any case, a low input of concentrates with a high magnesium content may be necessary for a few weeks after lambing to ensure that the ewes have an adequate intake of magnesium during early lactation.

In view of the small responses in the performance of ewes with twin lambs to concentrate supplements, it is unlikely that ewes at pasture with single lambs would respond to supplementation during early lactation (Treacher, 1990). So, in situations in which flock size is sufficient, some savings in concentrate costs can be made by grazing ewes with singles and those with two or more lambs separately and only providing concentrates for the latter.

Research in upland situations has indicated that no lasting response in animal performance to concentrate supplementation occurred when sward surface height was above 4 cm. However, although lambing is usually later in the uplands, the period before grass growth is sufficient to sustain a sward height of 4 cm in a stocked sward, is generally long compared to lowland situations, and so an extended period of concentrate feeding is likely to be necessary, especially in flocks with high lambing percentages.

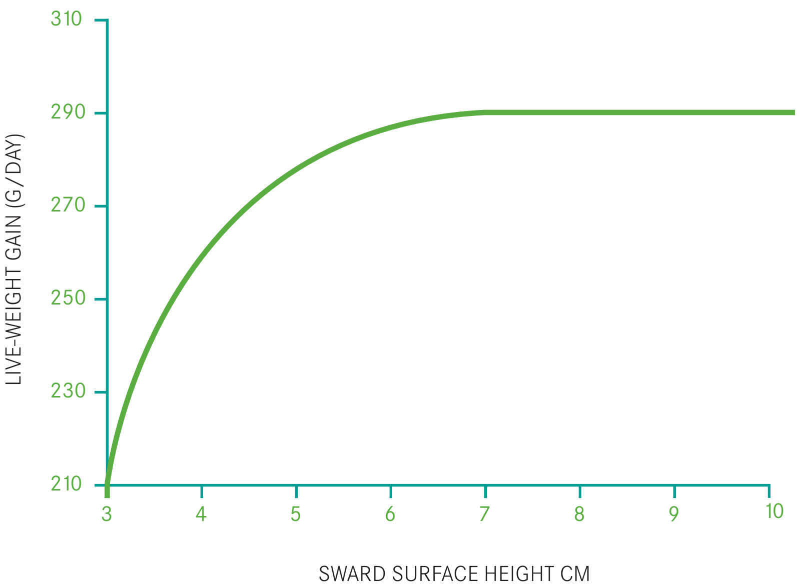
Controlling sward height in late spring and summer

The most difficult aspect of good grazing management is ensuring that the correct stocking rate is used throughout the grazing season, so that the feed requirements of the sheep are closely matched to the rate of grass growth. However this is essential to ensure efficient utilization of the pasture, while at the same time avoiding a shortage of grass which reduces the growth rate of the lambs, or having too much grass which wastes grass and results in a lot of stemmy grass of low digestibility, which in turn reduces animal performance later in the grazing season.

The results of a number of experiments have shown that there is a major reduction in the growth rate of twin lambs suckling their mothers, when the height of the sward grazed by the ewes and lambs falls below 5 to 6 cm. On the other hand, increases in the growth rate of suckling lambs when sward height has been increased above 6 cm have been small as shown in Figure 1. The results of a number of experiments have also indicated that the yield of grass/acre which sheep harvest from continuously grazed swards has been maximised when the swards have been maintained at a height of 4 to 6 cm (Maxwell and Treacher, 1987). Maintaining swards at this height during the early grazing season by continuous grazing produces a very dense sward with a high content of leaf and few seed heads. Consequently the decline in the digestibility of the sward through the grazing season is minimised and the decline in the digestibility of the herbage actually selected by the sheep has been negligible (Maxwell and Treacher, 1987).

Thus, the results of these experiments indicate that maintaining sward surface height as near as possible to 5 to 6 cm during the late spring and early summer should sustain near maximum growth rates in suckling lambs,

FIGURE 1. THE EFFECT OF SWARD SURFACE HEIGHT ON THE GROWTH RATE OF LAMBS FROM BIRTH UNTIL WEANING



while at the same time maximising the quantity of grass harvested/acre by the sheep. This approach also maintains a high quality sward which should enable high levels of animal performance to be achieved later in the season. Grazing management during this period from April to June is critical if a high level of performance is to be maintained, and at the same time the sward is to be kept short enough to prevent a deterioration in sward quality through the production of stemmy, seeded grass which will reduce performance later in the season.

The critical importance of maintaining tight control of grazed swards during the period April to mid June, when grass growth rates are maximum on lowland farms, usually necessitates closing off a major part of the grazing area, either by temporary electric fencing, or if fields are small by removing one or more fields from the grazing area. The grass on these areas should be cut for silage after a short regrowth interval, as this ensures that the aftergrass will be available quickly for grazing again and also maximises the quality of the silage produced.

This approach is similar to the use of a buffer grazing area which has been used successfully for beef cattle as described in Chapter 3. However, with sheep, because grazing usually starts earlier in the spring than with cattle, and demand for grass is high at this stage, the whole grassland area is grazed initially, and the areas to be cut for silage are closed off later, while with cattle at least part of the area to be harvested for silage is normally closed off from the beginning of the grazing season.

Grassland management during mid-summer and autumn

Although maintaining swards at a height of 5 to 6 cm during April to June, and thereby producing a good dense, leafy sward, has enabled high lamb growth rates to be maintained during this period, research information from Scotland indicates that, after mid-June, lamb growth rates may decline substantially when ewes and lambs continue to graze swards maintained at this constant height. For example, Keeling and others (1987) found that lamb growth rates declined from 0.30 to 0.35 kg/day in May and June to less than 0.20 kg/day in July and August when ewes and lambs grazed swards which were maintained at a constant height of either 4 to 6 cm or 6 to 8 cm. In this study, although maintaining a taller sward (i.e. 6 to 8 cm instead of 4 to 6 cm) increased the live-weight gain of the lambs from 0.25 to 0.27 kg/day, the difference between the two swards was small compared to the major decline in live-weight gain between the May/June and July/August periods on both swards.

Similarly, Lloyd and others (1987) recorded a live-weight gain of 0.32 kg/day for Suffolk cross twin lambs suckling Greyface ewes over the first 8 weeks of life, when they were grazing a 5 cm tall sward. From 8 to 16 weeks of age, the live-weight gain of the lambs was higher, at 0.27 kg/day, when sward height increased over the 8-week period than when it declined over the course of the 8-week period (live-weight gain of 0.24 kg/day), even though the average sward height over the 8-week period was similar for the two swards. However in one year of this three year study, the lambs achieved a live-weight gain of 0.31 kg/day when they had a liberal allowance of grass and sward height increased during the period. In this case the growth rate of the lambs at pasture was equal to the growth rate of similar lambs given a diet of concentrates ad libitum. Thus, these results demonstrate the potential of an adequate supply of high quality grass to sustain a high growth rate in lambs in the third and fourth months of life.

In a further experiment in Scotland, Vipond and others (1989) examined a range of grazing strategies to minimise the decline in the growth rate of lambs at pasture during July and August. Between 30 June and 1 September, ewes and their twin lambs grazed either perennial ryegrass swards or swards which were a mixture of perennial ryegrass and white clover, either at a constant sward height of 5 cm over the nine week period, or when the height of the sward declined slightly from 5 cm at the beginning of the period to 4 cm at the end of the period. From mid April until the end of June the perennial ryegrass sward sustained a live-weight gain of 0.28 kg/lamb/day while the grass/clover sward sustained a live-weight gain of 0.33 kg/lamb/day. However from the end of June to the beginning of September, lamb live-weight gains were only 0.08 and 0.14 kg/day on the grass and grass/clover swards respectively which decreased in height, compared to 0.17 and 0.25 kg/day for the grass and grass/clover swards which were maintained at a constant height over the period as shown in Table 40.

TABLE 40 THE EFFECT OF SWARD TYPE AND SWARD SURFACE HEIGHT ON THE LIVE-WEIGHT GAIN (KG/DAY) OF TWIN LAMBS DURING EARLY AND MID SUMMER

	SWARD TYPE	
	RYEGRASS	RYEGRASS/WHITE CLOVER
14 April to 30 June at a sward surface height of 6 cm	0.28	0.33
30 June to 1 September at a sward height of 5 cm	0.17	0.25
30 June to 1 September at a sward height of 5 cm declining to 4 cm	0.08	0.14

These results again demonstrate that with good grassland management, high growth rates can readily be achieved in twin lambs from April until June, but that it is much more difficult to sustain these high growth rates during July and August. However, Vipond and others (1989) found that a combination of using grass/clover swards and reducing the stocking rate sufficiently to allow sward height to rise during July and August can sustain live-weight gains of over 0.30 kg/day in twin lambs during this period.

There would appear to be less information on the effect of grazing management on the performance of weaned lambs. Chestnutt (1990) found that weaned lambs grazing a sward which had a surface height of 7 cm had a live-weight gain of 0.15 kg/day, while lambs grazing a sward with a height of 3 cm lost weight. Similarly, Doney and others (1987) found that when the height of a sward grazed by weaned lambs decreased from 6 down to 3 cm they lost weight, while lambs grazing at a lower stocking rate so that sward height increased from 3 to 6 cm gained 0.15 kg live weight/day.

This limited amount of information would indicate that weaned lambs are very sensitive to sward conditions, and that to achieve even reasonable growth rates during mid to late summer, a sward height of at least 5 cm is required. Also the stocking rate should be low enough to allow sward height to rise gradually as the season progresses to ensure that the lambs have a good supply of leafy grass in the sward.

Allowing sward height to rise to about 8 cm by August/September, when a major proportion of the lambs have been marketed, has not only been very advantageous in improving the growth rate of weaned lambs at this stage, but it has also allowed a build-up of extra grass which has been needed at this time of year to get the thinner ewes in the flock back into good body condition again at least a month before mating. As discussed in the previous chapter this is essential if lambing percentage in the following spring is to be maximised. It is also essential to avoid a rapid fall in sward height during and immediately after the mating period as this too can cause a substantial reduction in lambing percentage, so a good supply of grass in early autumn is needed to ensure that grass does not become scarce until well after mating.

The value of white clover in grass swards for sheep

The value of establishing and maintaining white clover in swards for sheep has been examined in several experiments. Newton and Davies (1987) reviewed research findings on herbage yields from grass swards fertilized with nitrogen and grass/clover swards which received no nitrogen fertilizer. They found that a good grass/clover sward without nitrogen fertilizer typically produced the same yield of herbage as a grass sward fertilized with 180 kg of nitrogen per ha. Thus maintaining a good distribution of clover in swards can enable considerable savings to be made in fertilizer costs.

A further important benefit of including clover in swards grazed by sheep is the potential of clover to sustain higher growth rates in lambs than grass. Newton and Davies (1987) reviewed the results of three experiments and found that weaned lambs grazing a grass/clover sward had an average live-weight gain of 0.15 kg/day compared to a live-weight gain of 0.09 kg/day for lambs grazing a pure grass sward. In a subsequent study at

TABLE 41 THE EFFECT OF GRASS AND GRASS/CLOVER SWARDS ON THE LIVE-WEIGHT GAIN OF LAMBS (KG/DAY)

	SWARD TYPE		% INCREASE WITH CLOVER
	GRASS	GRASS/CLOVER	
Weaned lambs (Average results of 12 comparisons)	0.08	0.13	60
Suckling lambs (Average results of 18 comparisons)	0.246	0.283	15

Hillsborough, Chestnutt (1992) reported that the live-weight gain of weaned lambs grazing grass/clover swards was 57% higher than that of lambs grazing pure grass swards. This higher level of performance was achieved, despite the fact that the clover contents of the swards were very low.

Overall, in 12 comparisons of pure grass and grass/clover swards, the live-weight gain of weaned lambs was 60% higher for the grass/white clover swards than for the grass swards as shown in Table 41, even though the clover content in some of the swards was low.

Vipond and others (1993a; 1993b and 1997) carried out an extensive series of studies over eight years to examine the performance of twin lambs suckling their mothers and grazing pure grass or grass/clover swards from April until weaning between mid July and the end of August. Both types of sward were managed to maintain a constant sward height of 4 to 6 cm from early April until the end of June. During July and August half of each sward was maintained at a constant height of around 4 cm while the other half of each sward was stocked at a lower rate to allow the height of the sward to rise gradually during the two month period from about 4 to 6 cm.

In the first three years of the study when there was a reasonably high content of clover in the grass/clover swards, the overall live-weight gain until weaning or marketing was 22% higher for the lambs on the grass/clover swards than for those on the grass swards (0.28 vs 0.23 kg/day). In this study the grass/clover sward sustained a very high live-weight gain of 0.34 kg/day during the first 12 weeks, from early April until the end of June. During July and August when the performance of lambs usually declines substantially, the grass/clover swards with the rising sward height still sustained an average live-weight gain of 0.26 kg/day. Consequently, even though the ewes did not start to lamb until the last week of March, 73% of the lambs grazing the grass/clover swards were finished before they were weaned, compared to only 14% of the lambs which were on the pure grass swards.

However, after five years of this major study, for other experimental reasons, the swards were managed in a way which was very detrimental to the survival of clover. Consequently in the last two years of the experiment the clover content of the swards was very low and there was no difference in the growth rates of the lambs grazing the grass and grass/clover swards. In two further three-year studies at Hillsborough and in Berkshire, Chestnutt (1992) and Orr and others (1990) also recorded live-weight gains of around 0.30 kg/day for twin lambs or a mixture of twin and single lambs on grass clover swards right through to weaning in July/August. However, in these studies the benefit of including clover in the swards on the live weight of the lambs was not as great as in the studies undertaken in Scotland by Vipond and others (1993a).

Consequently over a total of 18 comparisons of grass and grass/clover swards, the average daily live-weight gain of lambs until weaning was 15% higher for those on grass/clover swards as shown in Table 41.

The results of these experiments clearly demonstrate that a combination of using good grass/clover swards and a high standard of grazing management can enable live-weight gains of over 0.30 kg/day to be sustained in March/April born twin lambs from birth right through until three quarters of the lambs are slaughtered at a carcass weight of 20 kg, and the remainder are weaned at the end of August (Vipond and others, 1993a and 1993b). This combined with a potential 60% higher growth rate in weaned lambs on grass clover swards would enable nearly all lambs on lowland farms to be finished off pasture at minimum cost without the need for expensive supplementary feeding in late autumn/winter.

However the greatest limitation to the use of good grass/clover swards is maintaining a good clover content in the sward as discussed in Chapter 3 for beef cattle. Nevertheless there are only a few key factors in maintaining a good grass/clover sward. These are:

1. Ensuring that adequate lime, phosphate and potash are applied.
2. Ensuring that the swards are kept well grazed down during the early grazing season from April until late June. Excessive quantities of grass on grass/clover swards at this stage are very detrimental to the persistence of clover in the sward.
3. Resting the sward from grazing for one or preferably two periods of about three weeks between late June and early September to allow the clover to develop.
4. Ensuring that the swards are well grazed down in the late autumn/early winter. Again, leaving a lot of grass on the swards during the winter is very detrimental to the persistence of clover.
5. Restricting the application of nitrogen fertilizer to a maximum of 50 kg/ha (20 kg/acre) in early spring.

The effects of grazing cattle and sheep together rather than separately

Cattle and sheep have very different grazing habits and methods of grazing (Bullock and Armstrong, 2000). For example, sheep are very selective grazers while cattle have a low degree of selectivity. On the other hand, sheep tend to graze grass around dung pats, whereas cattle often reject this grass. Consequently in several experiments, grazing cattle and sheep together has resulted in better individual animal performance, higher output of live-weight gain per hectare and better utilization of swards.

Nolan and Connolly (1977) reviewed the results of early experiments which compared grazing cattle and sheep separately or together. The results of these experiments indicated that grazing cattle and sheep together increased lamb growth rate, sometimes increased the growth rate of the cattle, although the effects on the performance of the cattle were more variable, and produced a greater total output of animal product per hectare than when the cattle and sheep were grazed separately. The increase in the growth rate of the lambs was generally of the order of 10%.

In a subsequent, extensive experiment undertaken in the West of Ireland over four years, Nolan and Connolly (1989) recorded a 6% increase in the daily live-weight gain of lambs and a 15% increase in the live-weight gain of steers when they were grazed together compared to when they were grazed separately. Consequently, grazing cattle and sheep together rather than separately increased total live-weight gain/hectare by about 10%. On the other hand, Abaye and others (1994) found that grazing suckler cows and calves and ewes and lambs together rather than separately, increased the live-weight gain of the lambs by 45%, from 0.16 to 0.23 kg/day but did not affect the performance of the cattle.

Grazing cattle and sheep together can also help to reduce poaching during wet weather, because even though the overall stocking rate is the same, the number of cattle grazing/hectare is lower than when cattle are grazed alone. Grazing cattle and sheep together can also help to reduce the burden of parasitic worm larvae on the pasture because the number of either sheep or cattle grazed/hectare is lower than if they are grazed separately, and the economically important nematode worms of cattle and sheep are specific to that species (Cawthorne, 1986).

SUMMARY OF THE MAIN POINTS ON FEEDING BREEDING EWES AFTER LAMBING AND GRASSLAND MANAGEMENT FOR SHEEP

1. To achieve high growth rates in twin lambs, lowland ewes require about one kg of concentrates/ewe/day with high quality, precision-chopped silage, 1.5 kg concentrates with medium quality silage or hay and 2 kg concentrates with poor quality silage or hay.
2. Concentrates given to ewes after lambing should contain a high proportion of low-starch ingredients, especially when high concentrate inputs are being used.
3. With an adequate supply of spring grass, ewes can consume 3 kg of grass dry matter/ewe/day. At this level of intake there is unlikely to be a response to concentrate feeding except as a carrier for magnesium, in situations in which this is needed.
4. When the supply of grass has been very limited (i.e. a sward height of less than 3 to 4 cm), offering ewes rearing twin lambs a high-protein concentrate increased lamb growth rate.
5. Concentrates containing at least 16% protein have been more cost effective for ewes in early lactation than low protein, cereal-based concentrates.
6. To achieve high growth rates in lambs, swards grazed by ewes and lambs need to be kept well grazed down to a height of 4 to 6 cm during April to late June, to produce good dense, leafy swards.
7. The results of a number of experiments have shown that the performance of lambs is inclined to fall off substantially during July and August. Research has shown that this decline in performance during July and August can be minimised by ensuring that the sward is well grazed down in June to prevent the grass from becoming stemmy, and then reducing stocking rate to allow the height of the sward to rise gradually during July and August.
8. Using grass/white clover swards with a good distribution of clover rather than all-grass swards has increased the live-weight gain of lambs suckling their mothers by about 15%, and the live-weight gain of weaned lambs by about 60%.
9. Grazing cattle and sheep together rather than grazing the two species separately has generally increased the live-weight gain of lambs and overall output by about 10%.
10. A combination of good grassland management to maintain high quality, dense, leafy swards, adjusting stocking rate to allow sward height to rise during July and August and using good grass/clover swards can maintain very high live-weight gains of over 0.30 kg/day in twin lambs from birth to slaughter.
11. This can enable almost all twin lambs born in the lowlands in March/early April to be finished off pasture at minimal cost, without the need for expensive supplementary feeding.

SOURCES

OF RESEARCH INFORMATION USED IN THIS REVIEW

Abaye, A.O., Allen, V.G. and Fontenot, J.P. 1994. *Journal of Animal Science,* 72: 1013-1022.

Agnew, R.E. and Carson, M.T. 2000. *Grass and Forage Science,* 55: 114-124.

Alder, F.E., McLeod, D. St. L. and Gibbs, B.G. 1969. *Journal of the British Grassland Society,* 24: 199-206.

Allen, D. 1990. *Planned Beef Production and Marketing.* BSP Professional Books, Oxford.

Amer, P.R., Kemp, R.A. and Smith, C. 1992. *Canadian Journal of Animal Science,* 72: 759-771.

Anderson, R. 1985. *Record of Agricultural Research in Northern Ireland,* 33: 25-30.

Anderson, S.J., Merrill, J.K. and Klopfenstein, T.J. 1988a. *Journal of Animal Science,* 66: 2959-2964.

Anderson, S.J., Merrill, J.K., McDonnell, M.L. and Klopfenstein, T.J. 1988b. *Journal of Animal Science,* 66: 2965-2976.

Annett, R.W. and Carson, A.F. 2003. *Proceedings of the British Society of Animal Science, Annual Meeting,* p. 59.

Apolant, S.M. and Chestnutt, D.M.B. 1982. 55th *Annual Report of the Agricultural Research Institute of Northern Ireland,* pp. 30-37.

Apolant, S.M. and Chestnutt, D.M.B. 1985. *Animal Production,* 40: 287-296.

Appleton, M. 1987. In: *Efficient Sheep Production from Grass,* (editor G.E. Pollott). *British Grassland Society, Occasional Publication* No. 21, pp. 49-56.

Arthur, P.F., Makarechian, M. and Price, M.A. 1988. *Canadian Veterinary* Journal, 29: 163-167.

Baker, R.L., Carter, A.H., Morris, C.A., Johnson, D.L. and Hunter, J.C. 1986. *New Zealand Journal of Agricultural Research,* 29: 421-431.

Bell, J.M. 1993. *Canadian Journal of Animal Science,* 73: 679-697.

Bellows, R.A. and Short, R.E. 1978. *Journal of Animal Science,* 46: 1522-1528.

Black, H. and Chestnutt, D.M.B. 1989. Animal Production, 48: 633.

Breen, J. and Keane, G.P. 2000. *Proceedings of the Irish Grassland and Animal Production Association, 26th Annual Research Meeting,* pp. 177-178.

Browne, D. 1966. *Irish Journal of Agricultural Research,* 5: 89-101.

Browne, D. 1967. *Irish Journal of Agricultural Research,* 6: 73-81.

Browne, E.M., Bryant, M.J., Beever, D.E. and Fisher, A.V. 2000. *Proceedings of the British Society of Animal Science, Annual Meeting,* p. 72.

Bullock, D.J. and Armstrong, H.M. 2000. In: *Grazing Management. British Grassland Society, Occasional Symposium* No. 34, pp. 191-200.

Burrow, H.M. 1997. *Animal Breeding Abstracts,* 65: 477-495.

Burrow, H.M., Seifent, G.W. and Corbet, N.J. 1988. *Proceedings of the Australian Society of Animal Production,* 17: 154-157.

Cameron, N.D. and Drury, D.J. 1985. *Animal Production,* 40: 315-322.

Cameron, N.D., Smith, C. and Deeble, F.K. 1983. *Animal Production,* 37: 415-421.

Carson, A.F., Dawson, L.E.R. and Irwin, D. 2002. In: *Recent Research on Beef and Sheep Production. Agricultural Research Institute of Northern Ireland, Occasional Publication* No. 32, pp. 19-34.

Carson, A.F., Dawson, L.E.R. and Laidlaw, A.S. 2003. *Proceedings of the British Society of Animal Science, Annual Meeting,* p. 63.

Carson, A.F., Irwin, D. and Kilpatrick, D.J. 2001b. *Journal of Agricultural Science, Cambridge,* 137: 221-233.

Carson, A.F., McClinton, L.O.W. and Steen, R.W.J. 1999a. *Animal Science,* 68: 69-78.

Carson, A.F., Moss, B.W., Dawson, L.E.R. and Kilpatrick, D.J. 2001a. *Journal of Agricultural Science, Cambridge,* 137: 205-220.

Carson, A.F., Moss, B.W., Steen, R.W.J. and Kilpatrick, D.J. 1999b. *Animal Science,* 69: 81-92.

Carson, M.T. and Kennedy, S.J. 1991. *Proceedings of the Irish Grassland and Animal Production Association, Annual Research Meeting, Dublin,* pp. 145-146.

Cawthorne, R.J.G. 1986. In: Grazing, (editor J. Frame). British Grassland Society, Occasional Symposium No. 19, pp. 89-97.

Cheeke, P.R. 1999. *Journal of Animal Science,* 77: 2031-2038.

Chestnutt, D.M.B. 1990. In: *New Developments in Sheep Production, British Society of Animal Production, Occasional Publication* No. 14, pp. 125-128.

Chestnutt, D.M.B. 1992. *Grass and Forage Science,* 47: 70-80.

Conway, A. 1968. *Irish Journal of Agricultural Research,* 7: 105-120.

Corah, L.R., Dunn, T.G. and Kaltenbach, C.C. 1975. *Journal of Animal Science,* 41: 819-824.

Cowan, R.T., Robinson, J.J., McDonald, I. and Smart, R. 1980. *Journal of Agricultural Science, Cambridge,* 95: 497-514.

Cundiff, L.V. 1970. *Journal of Animal Science,* 30: 694-705.

D'Hour, P. and Petit, M.V. 1997. *Proceedings of the International Suckler Cow Workers Group Meeting, Yorkshire.*

Dawson, L.E.R. and Carson, A.F. 2002a. *Journal of Agricultural Science, Cambridge,* 139: 169-181.

Dawson, L.E.R. and Carson, A.F. 2002b. *Journal of Agricultural Science, Cambridge,* 139: 183-194.

Dawson, L.E.R., Carson, A.F. and Kilpatrick, D.J. 1999b. *Animal Feed Science and Technology,* 82: 21-36.

Dawson, L.E.R., Carson, A.F. and McClinton, L.O.W. 2002c. *Animal Science,* 75: 459-468.

Dawson, L.E.R., Carson, A.F., McClinton, L.O.W., Kilpatrick, D.J. and Moss, B.W. 2003. *Animal Science* (In press).

Dawson, L.E.R., Ferris, C.P., Steen, R.W.J., Gordon, F.J. and Kilpatrick, D.J. 1999a. *Grass and Forage Science,* 54: 237-247.

Dawson, L.E.R., Steen, R.W.J. and Ferris, C.P. 1998. *Proceedings of the British Society of Animal Science, Annual Meeting,* p. 43.

DiCostanzo, A., Chester-Jones, H., Plegge, S.D., Peters, T.M. and Meiske, J.C. 1990. *Animal Production,* 51: 75-84.

Dion, S. and Seoane, J.R. 1992. *Canadian Journal of Animal Science,* 72: 367-373.

Diskin, M.G. and Sreenan, J.M. 1990. *Irish Grassland and Animal Production Association Journal,* 24: 88-99.

Doney, J.M., Milne, J.A., White, I.R. and Colgrove, P. 1987. *Animal Production,* 44: 471.

Drennan, M.J. (undated). Report for C.S.E. Teo. Using feeding studies carried out at Grange and Moorepark to determine the energy value of molasses.

Drennan, M.J. 1985. In: *Feeding Value of By-products and their Use by Beef Cattle, (editor Ch. V. Boucque). Proceedings of a seminar in the CEC Programme of Co-ordination and Research on Beef Production,* Melle-Gontrode, Belgium, pp. 171-183.

Drennan, M.J. 1990. *Irish Grassland and Animal Production Association Journal,* 24: 67-77.

Drennan, M.J. and Moloney, A.P. 1998. *Proceedings of the Irish Grassland and Animal Production Association, Annual Research Meeting,* pp. 99-100.

Drennan, M.J., Moloney, A.P. and Keane, M.G. 1994. *Irish Journal of Agricultural and Food Research,* 33: 1-10.

Dunn, T.G., Ingalls, J.E., Zimmerman, D.R. and Wiltbank, J.N. 1969. *Journal of Animal Science,* 29: 719-726.

Evans, B. 1981. *Grass and Forage Science,* 36: 132-134.

Fallon, R.J. and Prendiville, P.J. 2000. In: *Profitable Production of Quality Beef.* Teagasc, Dublin, pp. 123-125.

Fallon, R.J., Drennan, M.J. and Keane, M.G. 2000. In: *Profitable Production of Quality Beef.* Teagasc, Dublin, pp. 32-35.

Forbes, T.J. and Jackson, N. 1971. *Journal of the British Grassland Society,* 26: 257-264.

Fredeen, H.T., Weiss, G.M., Rahnefeld, G.W., Lawson, J.E. and Newman, J.A. 1988. *Canadian Journal of Animal Science,* 68: 619-636.

French, P., O'Riordan, E.G., Moloney, A.P., O'Kiely, P., Caffrey, P.J., Stanton, C., Mooney, M.T. and Troy, D.J. 1998a. *Grange Research Centre, Research Report, Teagasc,* pp. 72-89.

French, P., O'Riordan, E.G., Moloney, A.P., O'Kiely, P., Humphreys, J. and Caffrey, P.J. 1998b. *Proceedings of the Irish Grassland and Animal Production Association, 24th Annual Research Meeting,* pp. 101-102.

Gallo, C.B. and Davies, D.A.R. 1988. *Animal Production,* 47: 111-121.

Galyean, M.L. 1996. *Journal of Animal Science,* 74: 2860-2870.

Gibb, M.J. and Treacher, T.T. 1980. *Journal of Agricultural Science, Cambridge,* 95: 631-640.

Gibb, M.J. and Treacher, T.T. 1982. *Animal Production,* 34: 123-129.

Grandin, T. 1980. *International Journal for the Study of Animal Problems,* 1: 313-337.

Gregory, K.E. and Cundiff, L.V. 1980. *Journal of Animal Science,* 51: 1224-1242.

Gregory, K.E., Cundiff, L.V. and Koch, R.M. 1991. *Journal of Animal Science,* 69: 3574-3589.

Gregory, K.E., Cundiff, L.V. and Koch, R.M. 1992. *Journal of Animal Science,* 70: 2366-2372.

Gregory, K.E., Cundiff, L.V., Koch, R.M., Laster, D.B. and Smith, G.M. 1978. *Journal of Animal Science,* 47: 1031-1041.

Grennan, E.J. 2000. *Proceedings of the Irish Grassland and Animal Production Association, Agricultural Research Forum,* pp. 47-48.

Grimble, R.F. 1998. *Proceedings of the Nutrition Society,* 57: 535-542.

Grundy, H.F., Wheeler, K.P.A. and Hardy, R. 1996. *Animal Science,* 63: 223-228.

Gunn, R.G. 1983. In: *Sheep Production,* (editor W. Haresign). Butterworths, London, pp. 99-110.

Gunn, R.G. and Doney, J.M. 1975. *Journal of Agricultural Science, Cambridge,* 85: 465-470.

Gunn, R.G. and Maxwell, T.J. 1989. *Animal Production,* 48: 471-474.

Gunn, R.G., Doney, J.M. and Russel, A.J.F. 1972. *Journal of Agricultural Science, Cambridge,* 79: 19-25.

Gunn, R.G., Maxwell, T.J., Rhind, S.M., Sim, D.A., Jones, J.R. and James, E. 1987. In: *Efficient Sheep Production from Grass, (editor G.E. Pollott). British Grassland Society, Occasional Symposium* No. 21, pp. 157-159.

Gunn, R.G., Russel, A.J.F. and Barthram, E. 1986. *Animal Production,* 43: 175-177.

Ha, Y.L., Grimm, N.K. and Pariza, M.W. 1987. *Carcinogenesis,* 8: 1881-1887.

Ham, G.A., Stock, R.A., Klopfenstein, T.J. and Huffman, R.P. 1995. *Journal of Animal Science,* 73: 353-359.

Hannah, S.M., Paterson, J.A., Williams, J.E. and Kerley, M.S. 1990. *Journal of Animal Science,* 68: 2536-2545.

Hanrahan, J.P. 1994. *Proceedings of the Irish Grassland and Animal Production Association, Agricultural Research Forum,* pp. 21-22.

Harris, W.S. 1989. *Journal of Lipid Research,* 30: 785-807.

Harte, J. and Fallon, R. 1981. *An Foras Taluntais, Animal Production Research Report,* p. 15.

Harte, J. and Fallon, R. 1982. *An Foras Taluntais, Animal Production Research Report,* p. 10.

Hibberd, C.A. and Chase, C.C. 1986. *Journal of Animal Science,* 63 (Supplement 1): 311.

Hickey, M.C. and French, P. 2000. *Grange Research Centre Research Report, Teagasc, Dublin,* pp. 102-109.

Hinks, C.E., Edwards, I.E. and Henderson, A.R. 1976. *Animal Production,* 22: 217-224.

Hohenboken, W. and Cochran, P.E. 1976. *Journal of Animal Science,* 42: 819-823.

Horn, G.W., Cravey, M.D., McCollum, F.T., Strasia, C.A., Krenzer, E.G. and Claypool, P.J. 1995. *Journal of Animal Science,* 73: 45-54.

Horton, G.M.J. and Holmes, W. 1974. *Journal of the British Grassland Society,* 29: 93-99.

Hsu, J.T., Faulkner, D.B., Garleb, K.A., Barclay, R.A., Fahey, G.C. and Berger, L.L. 1987. *Journal of Animal Science,* 65: 244-255.

Ingram, P.A. 2001. PhD Thesis. The Queen's University of Belfast.

Ip, C., Briggs, S.P., Haegele, A.D., Thompson, H.J., Storkson, J. and Scimeca, J.A. 1996. *Carcinogenesis,* 17: 101-106.

Ip, C., Chin, S.F., Scimeca, J.A. and Pariza, M.W. 1991. *Cancer Research,* 51: 6118-6124.

Ip, C., Scimeca, J.A. and Thompson, H.J. 1995. *Nutrition and Cancer,* 24: 241-247.

Jenkins, T.G. and Ferrell, C.L. 1992. *Journal of Animal Science,* 70: 1652-1660.

Johnston, S.D., Steen, R.W.J., Kilpatrick, D.J., Lowe, D.E. and Chestnutt, D.M.B. 1999. *Animal Science,* 68: 567-575.

Karalozos, A., Katanos, J. and Moustakas, G. 1985. In: *Feeding Value of By-products and their Use by Beef Cattle, (editor Ch. V. Boucque). Proceedings of a seminar in the CEC Programme of Co-ordination and Research on Beef Production,* Melle-Gontrode, Belgium, pp. 195-202.

Keady, T.W.J. 1996. *Irish Journal of Agricultural and Food Research,* 35: 141-150.

Keady, T.W.J. and Anderson, D. 2000. *Proceedings of the British Grassland Society, Research Conference, Aberdeen,* pp. 105-106.

Keady, T.W.J. and Steen, R.W.J. 1994. *Grass and Forage Science,* 49: 438-446.

Keady, T.W.J. and Steen, R.W.J. 1995. *Grass and Forage Science,* 50: 217-226.

Keane, M.G. 1993. *Irish Grassland and Animal Production Association Journal,* 27: 78-90.

Keane, M.G. and Drennan, M.J. 1980. *An Foras Taluntais, Animal Production, Research Report,* pp. 13-14.

Keane, M.G. and Drennan, M.J. 1981. *An Foras Taluntais, Animal Production, Research Report,* pp. 10-11.

Keane, M.G. and Drennan, M.J. 1982. *An Foras Taluntais, Animal Production, Research Report,* pp. 5-6.

Keane, M.G. and Drennan, M.J. 1988. *Irish Journal of Agricultural Research,* 27: 99-104.

Keane, M.G. and Drennan, M.J. 1989. *Grange Research Centre, Annual Report.* Teagasc, Dublin, pp. 162-163.

Keane, M.G. and Drennan, M.J. 1990. *Grange Research Centre Annual Report,* Teagasc, pp. 110.

Keane, M.G. and Drennan, M.J. 1992a. *Grange Research and Development Centre, Annual Report,* Teagasc, Dublin, pp. 162-163.

Keane, M.G. and Drennan, M.J. 1992b. *Grange Research and Development Centre, Annual Report,* Teagasc, Dublin, p. 163.

Keeling, B.J., Mackie, C.K., King, M.E. and Watt, C.W. 1987. *Animal Production,* 44: 485.

Kelly, P. 2000. In: *Profitable Production of Quality Beef.* Teagasc, Dublin, pp. 53-55.

Kempster, A.J., Cook, G.L. and Southgate, J.R. 1982a. *Animal Production,* 34: 167-178.

Kempster, A.J., Cook, G.L. and Southgate, J.R. 1982b. *Animal Production,* 35: 99-111.

Kempster, A.J., Cook, G.L. and Southgate, J.R. 1988. *Animal Production,* 46: 365-378.

Kempster, A.J., Croston, D., Guy, D.R. and Jones, D.W. 1987. *Animal Production,* 44: 83-98.

Kennedy, S.J. 1990a. *Grass and Forage Science,* 45: 17-28.

Kennedy, S.J. 1990b. *Grass and Forage Science,* 45: 281-288.

Kennedy, S.J., Gracey, H.I., Unsworth, E.F., Steen, R.W.J. and Anderson, R. 1989. *Grass and Forage Science,* 44: 371-380.

Kennelly, J.J., Mathison, G.W. and de Boer, G. 1988. *Canadian Journal of Animal Science,* 68: 811-820.

Kilpatrick, C., Keady, T., Cushnahan, A. and Murphy, J. 2001. *Costs of Forage on the Northern Ireland Dairy Farm. Greenmount College, DARD and the Agricultural Research Institute of Northern Ireland.*

Kilpatrick, D.J. and Steen, R.W.J. 1999. *Agricultural Systems,* 61: 95-107.

Kinsella, J.E., Lokesh, B. and Stone, R.A. 1990. *American Journal of Clinical Nutrition,* 52: 1-28.

Kirby, P.S., Chalmers, A.J. and Hannam, D.A.R. 1983. *Animal Production,* 36: 538.

Kirkland, R.M. and Patterson, D.C. 2003. *Proceedings of the British Society of Animal Science, Annual Meeting,* p. 10.

Kirkland, R.M., Steen, R.W.J. and Patterson, D.C. 2002. *Proceedings of the British Society of Animal Science, Annual Meeting,* p. 156.

Kirkland, R.M., Steen, R.W.J. and Patterson, D.C. 2003. Personal Communication.

Koots, K.R., Gibson, J.P., Smith, C. and Wilton, J.W. 1994. *Animal Breeding Abstracts,* 62: 309-338.

Laidlaw, A.S. 1984. *Grass and Forage Science,* 39: 317-321.

Laidlaw, A.S. and Stewart, T.A. 1987. *Research and Development in Agriculture,* 4: 155-160.

Langley, O.H. 1979. An Foras Taluntais, *Animal Production Research* Report. Report from Dunsinea, Moorepark and Western Centres, Dublin, pp. 61-62.

Laster, D.B. 1974. *Journal of Animal Science,* 38: 496-503.

Laster, D.B., Glimp, H.A., Cundiff, L.V. and Gregory, K.E. 1973. *Journal of Animal Science,* 36: 695-705.

Laster, D.B., Smith, G.M. and Gregory, K.E. 1976. *Journal of Animal Science,* 43: 63-70.

Latif, M.G.A. and Owen, E. 1979. *Journal of Agricultural Science, Cambridge,* 93: 235-239.

Latif, M.G.A. and Owen, E. 1980. *Animal Production,* 30: 311-314.

Leymaster, K.A. and Jenkins, T.G. 1993. *Journal of Animal Science,* 71: 859-869.

Linehan, J.J. 2000. In: *Profitable Production of Quality Beef.* Teagasc, Dublin, pp. 63-66.

Lloyd, M.D., Swift, G., Hunter, E.A., Swanston, S. and Doney, J.M. 1987. *Animal Production,* 44: 470-471.

Lordan, S. and Keane, G.P. 1999. *Proceedings of the Irish Grassland and Animal Production Association, 25th Annual Meeting,* pp. 103-104.

Lowe, D.E., Steen, R.W.J. and Beattie, V.E. 2001b. *Animal Welfare,* 10: 395-404.

Lowe, D.E., Steen, R.W.J., Beattie, V.E. and Moss, B.W. 2000. In: *Research Seminar on Ruminant Production. Agricultural Research Institute of Northern Ireland, Occasional Publication* No. 29, pp. 29-39.

Lowe, D.E., Steen, R.W.J., Beattie, V.E. and Moss, B.W. 2001a. *Livestock Production Science,* 69: 33-42.

Lowman, B.G. and Hill, G. 2002. Woodchip Corrals Information Pack. *Scottish Agricultural College.*

Lowman, B.G., Hinks, C.E., Hunter, E.A. and Scott, N.A. 1996. *Animal Science,* 63: 215-222.

Lowman, B.G., Hinks, C.E., Swift, G., Peebles, K. and Hunter, E.A. 1988. In: *Efficient Beef Production from Grass, (editor J. Frame). British Grassland Society, Occasional Symposium* No. 22, pp. 232-234.

Lowman, B.G., Neilson, D.R. and Hunter, E.A. 1985. *Animal Production,* 40: 538.

Lowman, B.G., Scott, N.A. and Sommerville, S.H. 1976. *East of Scotland College of Agriculture, Bulletin No. 6.*

Ludden, P.A., Cecava, M.J. and Hendrix, K.S. 1995. *Journal of Animal Science,* 73: 2706-2711.

Mann, T.J.L., Smith, C., King, J.W.B., Nicholson, D. and Sales, D.I. 1984. *Animal Production,* 39: 241-249.

Marsh, R. 1977. *Journal of the British Grassland Society,* 32: 25-32.

Marsh, R. and Laidlaw, A.S. 1978. *Journal of the British Grassland Society,* 33: 83-92.

Marsh, S.P. and Pullar, D. 2002. *Proceedings of the British Society of Animal Science, Annual Meeting,* p. 193.

Martin, T.G., Perry, T.W., Beeson, W.M. and Mohler, M.T. 1978. *Journal of Animal Science,* 47: 29-33.

Mathison, G.W. and Engstrom, D.F. 1995. *Canadian Journal of Animal Science,* 75: 637-640.

Maund, B.A. 1980. *Animal Production,* 30: 481.

Maund, B.A., Duffell, S.J. and Winkler, C.E. 1980. *Experimental Husbandry,* 36: 99-112.

Maxwell, T.J. and Treacher, T.T. 1987. In: *Efficient Sheep Production from Grass, (editor G.E. Pollott). British Grassland Society, Occasional Publication No. 21,* pp. 67-78.

McAdam, J.H. 1985. In: Grazing, (editor J. Frame). *British Grassland Society, Occasion Symposium No. 19,* pp. 210-212.

McCabe, N.H., O'Mara, F.P. and Caffrey, P.J. 1995. *Proceedings of the British Society of Animal Science, Winter Meeting,* Paper 162.

McGee, M. 1998. *Rapeseed meal as a feed ingredient.* R. & M. Hall, Technical Bulletin, No. 6.

McGuirk, B.J., Bourke, M.E. and Manwaring, J.M. 1978. *Australian Journal of Experimental Agriculture and Animal Husbandry,* 18: 753-763.

McGuirk, B.J., Going, I. and Gilmour, A.R. 1998. *Animal Science,* 66: 35-45.

McKelvey, W.A.C. and Robinson, J.J. 1986. *Annual Report of Studies in Animal Nutrition and Allied Sciences.* Rowett Research Institute, Vol 41: pp. 9-25.

McKervey, C., Lytle, S., O'Boyle, J. and McLauchlan, W. 2000. In: *Beef from Grass and Forage, (editor D. Pullar). British Grassland Society, Occasional Symposium No. 35,* pp. 165-168.

McLauchlan, W. and Johnston, S.D. 2000. In: *Beef from Grass and Forage, (editor D. Pullar). British Grassland Society, Occasional Symposium No. 35,* pp. 97-102.

Merrell, B.G. 1990. In: New Development in Sheep Production. *British Society of Animal Production, Occasional Publication No. 14,* pp. 138-141.

Meyer, D. and Mullinax, D.D. 1999. *Journal of Animal Science,* 77: Supplement 2/*Journal of Dairy Science,* 82: Supplement 2, pp. 51-62.

Milne, J.A., Maxwell, T.J. and Souter, W. 1981. Animal Production, 32: 185-195.

Moloney, D. and Murphy, W.E. 1963. *Irish Journal of Agricultural Research,* 2: 1-12.

More O'Ferrall, G.J. and Timon, V.M. 1977a. *Irish Journal of Agricultural Research,* 16: 267-275.

More O'Ferrall, G.J. and Timon, V.M. 1977b. *Irish Journal of Agricultural Research,* 16: 277-284.

Morgan, H. and Broadbent, J.S. 1980. *Animal Production,* 30: 476.

Morris, C.A., Baker, R.L., Carter, A.H. and Hickey, S.M. 1990. *Animal Production,* 50: 79-92.

Morris, C.A., Baker, R.L., Hickey, S.M., Johnson, D.L., Cullen, N.G. and Wilson, J.A. 1993. *Animal Production,* 56: 69-83.

Morris, C.A., Cullen, N.G., Kilgour, R. and Bremner, K.J. 1994. *New Zealand Journal of Agricultural Research,* 37: 167-175.

Muller, A. and Beranger, C. 1985. Report of experiments at the Experimental Department of Le Pin-au-Haras, Orne.

Muller, A., Beranger, C., Pecatte, G. and Gallard, Y. 1985. Report of experiments at the Experimental Department of Le Pin-au-Haras, Orne.

Newton, J.E. and Davies, D.A. 1987. In: *Efficient Sheep Production from Grass, (editor G.E. Pollott). British Grassland Society, Occasional Publication No. 21,* pp. 79-87.

Newton, J.E., Wilde, R. and Betts, J.E. 1985. *Research and Development in Agriculture,* 2: 1-6.

Nolan, T. and Connolly, J. 1977. *Herbage Abstracts,* 47: 367-374.

Nolan, T. and Connolly, J. 1989. *Animal Production,* 48: 519-533.

O'Gorman, C., Caffrey, P.J. and Keane, G.P. 1998. *Proceedings of the Irish Grassland and Animal Production Association, 24th Annual Research Meeting,* pp. 219-220.

O'Hagan, J.C. and Steen, R.W.J. 2000. *Proceedings of the British Society of Animal Science, Annual Meeting,* p. 125.

O'Kiely, P. 1996. *Irish Journal of Agricultural and Food Research,* 35: 1-15.

O'Kiely, P. 2000. In: *Profitable Production of Quality Beef.* Teagasc, Dublin, pp. 36-39.

O'Kiely, P. and Flynn, A.V. 1987. In: *Grass Silage, Beef Series No. 5, An Foras Taluntais, Dublin,* p. 45.

O'Kiely, P. and Moloney, A.P. 1995. *Irish Journal of Agricultural and Food*

Research, 34: 76.

O'Kiely, P. and Moloney, A.P. 1998. *Grange Research Centre, Annual Report, Teagasc,* pp. 42-44.

O'Kiely, P. and Moloney, A.P. 2000. *Proceedings of the Irish Grassland and Animal Production Association, 26th Annual Research Meeting,* pp. 99-100.

O'Kiely, P. and Moloney, A.P. 2002. *Proceedings of the Irish Grassland and Animal Production Association, Annual Research Meeting,* p. 42.

O'Kiely, P. and Poole, D.B.R. 1989. *Proceedings of the 40th Annual Meeting of the European Association for Animal Production,* Paper N3.10.

O'Kiely, P., Flynn, A.V. and Wilson, R.K. 1988. *Irish Journal of Agricultural Research,* 27: 39-50.

O'Neill, B.J., Drennan, M.J. and Caffrey, P.J. 2000. *Proceedings of the Irish Grassland and Animal Production Association, 26th Annual Research Meeting,* pp. 77-78.

O'Neill, B.J., Drennan, M.J. and Caffrey, P.J. 2001. *Proceedings of the British Society of Animal Science, Annual Meeting,* p. 116.

O'Riordan, E.G. 1995. *Proceedings of the Irish Grassland and Animal Production Association, 21st Annual Research Meeting,* pp. 155-156.

O'Riordan, E.G. 1996. *Proceedings of the Irish Grassland and Animal Production Association, 22nd Annual Research Meeting,* pp. 117-118.

O'Riordan, E.G. 1997. *Proceedings of the Irish Grassland and Animal Production Association, 23rd Annual Research Meeting,* pp. 193-194.

O'Riordan, E.G., Travers, G. and French, P. 1998. *Proceedings of the Irish Grassland and Animal Production Association, 24th Annual Research Meeting,* pp. 105-106.

Oltjen, R.R., Putman, P.A., Williams, E.E. and Davis, R.E. 1966. *Journal of Animal Science,* 25: 1000-1004.

Orr, R.J. and Treacher, T.T. 1994. *Animal Production,* 58: 109-116.

Orr, R.J., Parsons, A.J., Penning, P.D. and Treacher, T.T. 1990. *Grass and Forage Science,* 45: 325-336.

Orr, R.J., Parsons, A.J., Treacher, T.T. and Penning, P.D. 1988. *Grass and Forage Science,* 43: 199-207.

Osoro, K. and Wright, I.A. 1992. *Journal of Animal Science,* 70: 1661-1666.

Parker, J.W.G. and Crawshaw, R. 1982. *Grass and Forage Science,* 37: 53-58.

Patterson, D.C., Moore, C.A. and Steen, R.W.J. 1994. *Animal Production,* 58: 41-47.

Patterson, D.C., Steen, R.W.J., Moore, C.A. and Moss, B.W. 2000. *Animal Science,* 70: 171-179.

Peck, D.N. 2000. In: *Grazing Management. British Grassland Society, Occasional Symposium No. 34,* pp. 249-250.

Penning, P.D., Orr, R.J. and Treacher, T.T. 1988. *Animal Production,* 46: 403-415.

Petit, H.V., Veira, D.M. and Yu, Y. 1994. *Journal of Animal Science,* 72: 3221-3229.

Pullar, D. 1995. *Animal Science,* 60: 49-54.

Rastogi, R., Boylan, W.J., Rempel, W.E. and Windels, H.F. 1982. *Journal of Animal Science,* 54: 524-532.

Rhind, S.M., Doney, J.M., Gunn, R.G. and Leslie, I.D. 1984. *Animal Production,* 38: 201-209.

Richards, M.W., Spitzer, J.C. and Warner, M.B. 1986. *Journal of Animal Science,* 62: 300-306.

Robinson, J.J. 1983a. In: *Sheep Production,* (editor W. Haresign). Butterworths, London, pp. 111-131.

Robinson, J.J. 1983b. In: *Recent Advances in Animal Nutrition,* (editor W. Haresign). Nottingham University Press, pp. 143-161.

Robinson, J.J. 1990. In: *New Developments in Sheep Production. British Society of Animal Production, Occasional Publication No. 14,* pp. 55-69.

Robinson, J.J. 1995. Personal Communication.

Robinson, J.J., Fraser, C., Gill, J.C. and McHattie, I. 1974. *Animal Production,* 19: 331-339.

Schils, R.L.M., Vellinga, Th.V. and Kraak, T. 1999. *Grass and Forage Science,* 54: 19-29.

Selk, G.E., Wettemann, R.P., Lusby, K.S., Oltjen, J.W., Mobley, S.L., Rasby, R.J. and Garmendia, J.C. 1988. *Journal of Animal Science,* 66: 3153-3159.

Sinclair, K.D., Yildiz, S., Quintans, G. and Broadbent, P.J. 1998. *Animal Science,* 66: 643-655.

Smith, G.M., Laster, D.B. and Gregory, K.E. 1976. *Journal of Animal Science,* 43: 27-36.

Smith, J.F. and Knight, T.W. 1990. In: *Reproductive Management of Grazing Ruminants in New Zealand, Occasional Publication No. 12 of the New Zealand Society of Animal Production, pp. 113-143. Cited by Carson, A.F., Dawson, L.E.R. and Irwin, D. 2002. In: Recent Research on Beef and Sheep Production, Agricultural Research Institute of Northern Ireland, Occasional Publication No. 32,* pp. 19-34.

Spitzer, J.C., Morrison, D.G., Wettemann, R.P. and Faulkner, L.C. 1995. *Journal of Animal Science,* 73: 1251-1257.

Steen, R.W.J. 1978. PhD Thesis. The Queen's University of Belfast.

Steen, R.W.J. 1984a. *Grass and Forage Science,* 39: 35-41.

Steen, R.W.J. 1984b. 57th *Annual Report of the Agricultural Research Institute of Northern Ireland,* pp. 21-32.

Steen, R.W.J. 1984c. *Proceedings of the 7th Silage Conference,* The Queen's University of Belfast, pp. 113-114.

Steen, R.W.J. 1985a. *Animal Production,* 41: 281-291.

Steen, R.W.J. 1985b. *Animal Production,* 41: 301-308.

Steen, R.W.J. 1986. *Animal Production,* 42: 29-37.

Steen, R.W.J. 1988a. In: *Efficient Beef Production from Grass, (editor J. Frame). British Grassland Society, Occasional Symposium No. 22,* pp. 129-139.

Steen, R.W.J. 1988b. *Animal Production,* 46: 43-51.

Steen, R.W.J. 1988c. *Animal Production,* 47: 21-28.

Steen, R.W.J. 1989. *Animal Production,* 48: 81-89.

Steen, R.W.J. 1990. *Irish Grassland and Animal Production Association Journal,* 24: 56-66.

Steen, R.W.J. 1991a. In: *Recent Research on Beef. Agricultural Research Institute of Northern Ireland, Occasional Publication No. 20,* pp. 41-44.

Steen, R.W.J. 1991b. *Animal Production,* 52: 465-475.

Steen, R.W.J. 1992a. *Grass and Forage Science,* 47: 239-248.

Steen, R.W.J. 1992b. *Animal Production,* 54: 333-339.

Steen, R.W.J. 1993a. *Animal Production,* 56: 61-67.

Steen, R.W.J. 1993b. *Proceedings of the 10th International Conference on Silage Research,* pp. 206-207.

Steen, R.W.J. 1994. *Animal Production,* 58: 209-219.

Steen, R.W.J. 1995a. *Livestock Production Science,* 42: 1-11.

Steen, R.W.J. 1995b. *Animal Production,* 60: 556.

Steen, R.W.J. 1996a. *Journal of Agricultural Science, Cambridge,* 127: 403-412.

Steen, R.W.J. 1996b. In: *Research on Beef Production. Agricultural Research Institute of Northern Ireland, Occasional Publication No. 22,* pp. 61-70.

Steen, R.W.J. 1996c. In: *Research on Beef Production. Agricultural Research Institute of Northern Ireland, Occasional Publication No. 22,* pp. 5-13.

Steen, R.W.J. 1996d. In: *Research on Beef Production. Agricultural Research Institute of Northern Ireland, Occasional Publication No. 22,* pp. 53-59.

Steen, R.W.J. 1998a. In: *Research on Ruminant Production. Agricultural Research Institute of Northern Ireland, Occasional Publication No. 26,* pp. 49-64.

Steen, R.W.J. 1998b. *71st Annual Report of the Agricultural Research Institute of Northern Ireland,* pp. 30-41.

Steen, R.W.J. 2000. In: *Beef from Grass and Forage. British Grassland Society, Occasional Symposium No. 35,* pp. 55-64.

Steen, R.W.J. 2002. *Grass and Forage Science,* 57: 401-404.

Steen, R.W.J. and Kilpatrick, D.J. 1995. *Livestock Production Science,* 43: 205-213.

Steen, R.W.J. and Kilpatrick, D.J. 1998. *Animal Science,* 66: 129-141.

Steen, R.W.J. and Kilpatrick, D.J. 2000. *Livestock Production Science,* 62: 181-192.

Steen, R.W.J. and Laidlaw, A.S. 1995. *Irish Journal of Agricultural and Food Research,* 34: 123-132.

Steen, R.W.J. and Moore, C.A. 1988. *Animal production,* 47: 29-37.

Steen, R.W.J. and Moore, C.A. 1989. *Animal Production,* 49: 233-240.

Steen, R.W.J. and Porter, M.G. 2003. *Grass and Forage Science,* 58: 50-57.

Steen, R.W.J. and Robson, A.E. 1995. *Journal of Agricultural Science, Cambridge,* 125: 125-135.

Steen, R.W.J., Gordon, F.J., Dawson, L.E.R., Park, R.S., Mayne, C.S., Agnew, R.E., Kilpatrick, D.J. and Porter, M.G. 1998. *Animal Science,* 66: 115-127.

Steen, R.W.J., Ingram, P.A. and Comerford, J.W. 1999. *Proceedings of the International Suckler Cow Workers Group Meeting, Draperstown, Northern Ireland.*

Steen, R.W.J., Kilpatrick, D.J. and Porter, M.G. 2002. *Grass and Forage Science,* 57: 279-291.

Steen, R.W.J., Lavery, N.P., Kilpatrick, D.J. and Porter, M.G. 2003. *New Zealand Journal of Agricultural Research,* 46: 69-81.

Stone, C. and Appleton, M. 1986. *Animal Production,* 42: 454-455.

Stricklin, W.R., Heisler, C.E. and Wilson, L.L. 1980. *Journal of Animal Science,* 51: Supplement 1, pp. 109-110.

Subak, S. 1999. *Ecological Economy,* 30: 79-91.

Swift, G., Lowman, B.G., Scott, N.A., Peebles, K., Neilson, D.R. and

Hunter, E.A. 1989. *Research and Development in Agriculture,* 6: 91-97.

Thomas, O.O. and Geissler, B.R. 1968. *Journal of Animal Science,* 27: 1115.

Treacher, T.T. 1983. In: *Sheep Production,* (editor W. Haresign). Butterworths, London, pp. 133-153.

Treacher, T.T. 1990. In: *New Developments in Sheep production. British Society of Animal Production, Occasional Publication No. 14,* pp. 45-54.

Vanderwent, W., Berger, L.L., McKeith, F.K., Baker, A.M., Gonyou, H.W. and Bechtel, P.J. 1985. *Journal of Animal Science,* 61: 310-319.

Vesely, J.A. and Peters, H.F. 1972. *Canadian Journal of Animal Science,* 52: 283-293.

Vipond, J.E., King, M.E. and Inglis, D.M. 1987. *Animal Production,* 45: 211-221.

Vipond, J.E., Milne, J.A., Swift, G., Fitzsimons, J., McClelland, T.H. and Hunter, E.A. 1989. *Animal Production,* 48: 648.

Vipond, J.E., Swift, G., Cleland, A.T., Fitzsimmons, J. and Hunter, E.A. 1997. *Grass and Forage Science,* 52: 99-109.

Vipond, J.E., Swift, G., McClelland, T.H., Fitzsimmons, J., Milne, J.A. and Hunter, E.A. 1993a. *Grass and Forage Science,* 48: 290-300.

Vipond, J.E., Swift, G., Noble, R.C. and Horgan, G. 1993b. *Animal Production,* 57: 253-261.

Waterhouse, A., Laird, R. and Arnot, D.P. 1985. *Animal Production,* 40: 538.

Weber, P.C. and Leaf, A. 1991. *World Review of Nutrition and Diet, Basel, Karger,* 66: 218-232.

Weiss, W.P., Trenkle, A.M., Berger, L.L., Perry, T.W., Brandt, R.J., Rust, S.R., Larson, B., Williams, J.E., Stock, R.A., Loerch, S.C., Pritchard, R.H., Schaefer, D.M., Eisemann, J.H., Richards, C.R. and Topel, D.G. 1989. *Corn gluten feed in beef cattle diets. North Central Regional Research Publication No. 319, Ohio Agricultural Research and Development Centre, Special Circular No. 129.*

Wierenga, H.K. 1987. In: *Welfare Aspects of Housing Systems for Veal Calves and Fattening Bulls.* Commission of the European Communities, Luxembourg, pp. 105-122.

Wilkinson, S.C. and Chestnutt, D.M.B. 1988. *Animal Production,* 46: 63-70.

Williams, D.B., Vetter, R.W., Burroughs, W. and Topel, D.G. 1975. *Journal of Animal Science* 41: 1525-1531.

Wiltbank, J.N., Rowden, W.W., Ingalls, J.E. and Zimmerman, D.R. 1964. *Journal of Animal Science,* 23: 1049-1053.

Wiltbank, J.N., Rowden, W.W., Ingalls, J.E., Gregory, K.E. and Koch, R.M. 1962. *Journal of Animal Science,* 21: 219-225.

Wolf, B.T., Smith, C. and Sales, D.I. 1980. *Animal Production,* 31: 307-313.

Wright, D.A. 1997. PhD Thesis. The Queen's University of Belfast.

Wright, D.A., Gordon, F.J., Steen, R.W.J. and Patterson, D.C. 2000. *Grass and Forage Science,* 55: 1-13.

Wright, I.A. and Russel, A.F.J. 1991. *Animal Production,* 52: 105-113.

Wright, I.A., Rhind, S.M. and Whyte, T.K. 1992a. *Animal Production,* 54: 143-146.

Wright, I.A., Rhind, S.M., Russel, A.F.J., Whyte, T.K., McBean, A.J. and McMillen, S.R. 1987. *Animal Production,* 45: 395-402.

Wright, I.A., Rhind, S.M., Whyte, T.K. and Smith, A.J. 1992b. *Animal Production,* 55: 41-46.

Yiakoumettis, I.M. and Holmes, W. 1972. *Journal of the British Grassland Society,* 27: 183-191.

Young, N.E., Newton, J.E. and Orr, R.J. 1980. *Grass and Forage Science,* 35: 197-202.

Zinn, R.A. 1993. *Journal of Animal Science,* 71: 3-10.

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