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Breeding for Resistance to Footrot in Sheep

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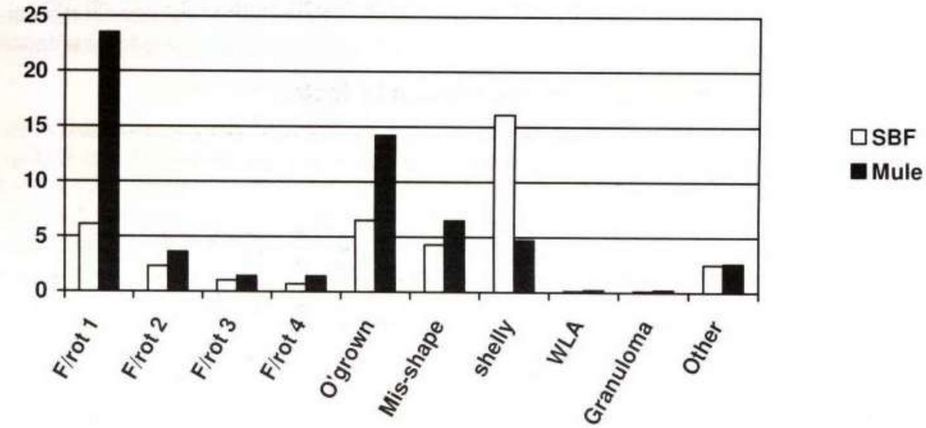
Introduction
Breeding for resistance to disease is not a new concept - farmers and sheep breeders have been doing it for centuries. However, the more recent use of estimated breeding values (EBVs) and new technologies such as DNA genotyping are essential tools in the current era of animal breeding, which have the potential to be used for breeding for resistance to footrot.

Footrot in sheep is a major welfare problem. It is the main cause of lameness, and is estimated to cost the UK sheep industry around £24M per annum (Nieuwhof and Bishop, 2005). Footrot-affected sheep frequently experience pain, discomfort and have reduced mobility that affects their ability to compete for feed (Abbot and Lewis, 2004). Affected sheep are also more susceptible to other diseases because of their weakened condition. The causative organism is *Dichelobacter (Bacteroides) nodosus (D. nodosus*), which is highly contagious, being easily transmitted from sheep to sheep *via* pasture, bedding or handling pens. Considerable effort is expended to manage footrot in such a way as to minimise its impact on the productivity of sheep flocks, such as footbathing with formalin or zinc sulphate, the use of antibiotic sprays, vaccination and foot trimming. However, these treatments are generally labour-intensive and are costly both in economic and environmental terms. Initial research at SAC has shown that there is a wide variation in the prevalence of footrot between offspring of different sires, with some having up to 25% of offspring affected, and others having none. This shows that the exploitation of the genetic basis for footrot resistance is likely to offer a long-term and sustainable solution to breeding healthier sheep.

Prevalence of footrot in UK sheep flocks
At a recent SAC footrot workshop (Hosie, 2004), footrot was identified as being a serious welfare problem that has major implications for flock productivity. In a recent survey of farmers' practices and attitudes towards footrot (Wassink and Green, 2001; Hosie, 2003), more than 90% of sheep farmers had seen footrot in their sheep in the past year and 31% considered that 6% or more of their flock were affected with footrot. In these surveys, which rely on farmers' diagnoses, the prevalence of footrot could be overstated because farmers may not distinguish footrot from other causes of foot lameness (such as scald and Contagious Ovine Digital Dermatitis, CODD). It can also be argued that these estimates may be understated because of failure to diagnose early predisposing foot conditions, e.g. 'scald', where there are signs of inflammation of the interdigital skin. This can only be seen if individual feet are inspected, as this condition is not always accompanied by lameness. Also, recent results from research that is currently underway in the UK have shown that the prevalence of footrot is much higher than in the other studies cited in the questionnaires reported above. In 2005, 3,852 Scottish Blackface and Mule sheep located on experimental flocks in Scotland, England and Wales had each foot inspected and scored for foot lesions individually. The results from these inspections show that overall, 16% of all feet

were affected, which equates to 44% of all sheep being affected. There were large differences between flocks, with 25% of Blackface sheep and 56% of mule sheep being affected. However, it is important to note that these figures cannot be used as a breed comparison, because none of the flocks scored had both breeds running together as one flock. Figure 1 shows the prevalence of the footrot and other foot conditions, with scores 1-4 representing different severities of footrot (1 = inflammation of the interdigital skin and score 4 = severe under-running of the hoof).

Figure 1. Prevalence of footrot in Scottish Blackface (SBF) and Mule sheep



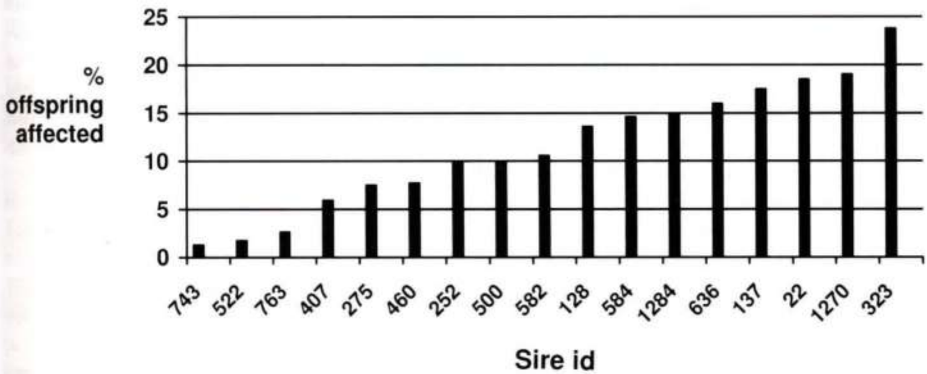
F/rot1 = footrot score1, F/rot2=footrot score 2. F/rot3=footrot score 3, F/rot 4=footrot score 4, o'grown=overgrown, mis-shape=mis-shapen, shelly = shelly hoof, WLA=White line abcess

Genetic variation in resistance to footrot

The exploitation of inherent, or natural resistance to footrot to implement genetic selection to reduce footrot incidence has been undertaken since the 1980's in Australia. Using Merino sheep, a footrot lesion scoring method was developed, with severity scored on a scale of 0 to 4 (Egerton and Roberts, 1971). Successful breeding for enhanced footrot resistance in Merinos has been described using this approach (Patterson and Patterson, 1989), and an evaluation of lines of Corriedale ewes selected for enhanced footrot resistance, in New Zealand, has been reported (Skerman and Moorhouse, 1987). The scoring system was further developed with sub-classes that separated clinical signs into 8 categories (Raadsma, 2000). An application of this 8-point scoring system in a genetic study following challenge and subsequent vaccination concluded that there is substantial genetic variation in resistance to challenge with virulent isolates of *D. nodosus* (Raadsma *et al.*, 1994). Heritability estimates of between 0.09 and 0.4 for several different immune response parameters were reported. It is likely that conventional breeding for resistance to footrot can be formalised into EBVs for resistance to footrot, so that appropriate weighting can be attributed to it, in relation to other breeding goals such as growth rate. Indeed, current research in the UK aims to quantify genetic variation in footrot in the Texel and Scottish Blackface breeds initially, and investigate the rates of response to selection from the use of EBVs for footrot as part of multi-trait breeding programmes in these breeds.

Research at SAC using Scottish Blackface sheep reared on two contrasting hill environments has developed breeding indices for hill breeds combining carcass and maternal characteristics (Conington *et al.*, 2001, 2004, 2006). As part of that research, health records on animals kept in the flocks have been maintained so that the effects of selection on the long-term health of different genetic lines can be determined. These data were used to look at whether or not differences exist in footrot between lambs from different sires. Figure 2 shows the results for 17 out of a total of 33 sires used across the two SAC hill flocks. Each bar of the graph represents the percentage of lambs that were treated for footrot according to individual sires. Each sire had an average of 44 progeny, and the other 16 sires (not shown on the graph) had no progeny that were treated for footrot. The results show clearly that there is a large difference between sires in the percentage of progeny treated for footrot.

Figure 2. Sire differences in % progeny affected by footrot

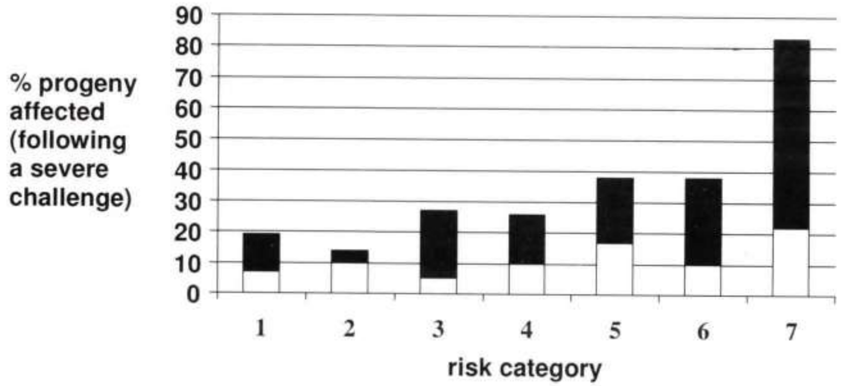


The use of Molecular genetics in breeding for resistance to footrot

Although conventional methods of selection for footrot resistance have been proven to be successful, the development and additional use of a molecular genetic test for footrot resistance potentially has enormous advantages. This is because of the practical difficulty of objectively scoring feet lesions, and of classifying them objectively and repeatably. In addition, with genetic markers, animals that are candidates for selection do not have to be exposed to infection to determine whether they are genetically susceptible or not. Additionally, this method can shorten the generation interval and hence accelerate responses to selection for resistance. Therefore, genetic markers potentially offer a practical alternative to laborious scoring, and protocols that require exposure to infection. The exploitation of genotype information *via* the use of genetic markers associated with resistance to footrot, potentially allows breeders to select sheep to breed for increased footrot resistance. A group of genes important for controlling immune response lies within the Major Histocompatibility Complex (MHC) on chromosome 20 in sheep. These genes show great genetic diversity between individuals, and it is thought that some alleles are more efficient at initiating an immune response to specific pathogens than others. Data exist, which suggest an association between genetic polymorphisms within the MHC Class II region and response to footrot infection (Litchfield *et al.*, 1993; Escayg *et al.*, 1997). Indeed, genetic variation within the ovine MHC loci in the class II region, specifically at the *DQA2* gene, has subsequently been used by Lincoln University, New Zealand (NZ) to develop genetic markers for footrot resistance (Hickford *et al.*, 2004).

Molecular testing for footrot resistance
A footrot test, based on the association of different DQA2 alleles and footrot resistance in sheep breeds in NZ is now commercially available to the NZ sheep industry to select more tolerant or resistant animals, without having to expose the animals to infection (Hickford, 2000). The NZ test categorises animals according to their risk of contracting footrot, following a severe footrot challenge. Figure 3 shows the categories, with the best groups predicted to have between 7 and 19% of offspring affected following a severe challenge, and the least resistant category to have between 22 and 83% of offspring affected. More than 28,000 sheep have now been genotyped in NZ for 258 ram breeder clients and it is estimated that over 1 million sheep have already been born to rams that have been screened using the 'NZ footrot DNA test'. The results of a recent report on the use of footrot-gene tested sheep show a reduction in production losses attributable to footrot of between 60 and 80% which, over a ten-year period, is estimated to be worth between $NZ 3M and $NZ 6M per annum (Greer, 2004). While it is possible that the NZ information will be relevant to sheep populations in the UK, it is not appropriate or advisable to use the NZ test on UK sheep breeds under local conditions without prior testing. This is because it is possible that UK breeds have unknown and different haplotypes in the DNA region tested, or the genetic background interacts with the underlying genes differently, or simply, that the associations between resistance and susceptibility, and genotype categories are different (Such validation processes are also required for gene tests for other traits and in other livestock species that have been developed in different breeds and different countries).

Figure 3. New Zealand footrot gene test categories



Note: Different colours show that (e.g.) between 7 and 19% of sheep with gene test category 1 will show footrot symptoms following a severe footrot challenge
(J. Hickford, *pers. comm.*)

New footrot research – combining conventional breeding with molecular testing
A new LINK-funded research project led by SAC started in 2005, builds on the research undertaken in NZ on footrot resistance.
The aims of the project are,
To test and further develop a robust scoring procedure to enable studies of the genetic control of footrot resistance;

To estimate heritabilities for footrot resistance using the information generated from the footrot scores and to explore the relationships (genetic correlations) between footrot resistance and other traits of economic importance such as lamb weights and maternal characteristics;
To investigate associations between footrot resistance and (a) polymorphisms at the DQA2 gene (the 'NZ footrot DNA test'), and (b) other genetic markers within and close to the MHC region;
To predict the genetic, epidemiological and total financial benefits from breeding for footrot resistance. This project will provide options to enable breeders to select animals for enhanced resistance to footrot combining both phenotypic information and molecular genetic information.

Even in the event that the genetic markers are not sufficiently strongly associated with footrot resistance in UK breeds under local environments, or that they prove to be not economically viable, breeders will still have the option of using Best Linear Unbiased Prediction (BLUP)-based selection to maximise the utility of phenotypic information.

The project is testing flocks of Texel, Blackface and Mule sheep across the UK and taking blood samples to be used for DNA analyses. To date, 3,853 animals have been scored at least once on experimental flocks at SAC, IRS and ADAS.

Benefits of footrot-resistant breeding stock

There are four main categories of benefit from having more footrot-resistant breeding stock, all of which should lead to improvements in the sustainability of sheep farming in the UK. These are: i) animal welfare benefits, as fewer animals are likely to be affected by, and involuntarily culled for, footrot with every successive generation, ii) economic benefits, as it is anticipated that the current estimated cost of footrot of £24M will be reduced by lower need for handling and treatments, iii) environmental benefits, as the use of formalin, zinc sulphate and antibiotics will be reduced in animal populations that are more resistant to footrot; and iv) improved societal acceptance, as the successful breeding for enhanced resistance will lead to fewer lame sheep in our landscape, which will improve public acceptability of sheep farming. This is an issue of growing importance as public access to the countryside widens.

Conclusions and future prospects

It is clear that the problem of footrot in sheep can be alleviated through the use of breeding strategies to select footrot-resistant breeding stock. The use of sustainable breeding solutions has been demonstrated to be effective in sheep populations in other parts of the world, and it is likely that they will be also be used in the UK in the near future. Recent research underway in the UK has shown that within-breed genetic variation exists in the expression of footrot, which is a cornerstone in the tool pack of sheep breeders that are breeding footrot-resistant sheep. The UK-wide footrot research consortium uses the expertise of international scientists, and evidence from flocks across Britain. It aims to use state-of-the-art genomic information in tandem with foot scores from several thousand animals so that the 'best' way to breed footrot-resistant sheep can be determined, and taken up by the UK sheep industry.

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Observations on Variation in Weight and Classification of Carcasses from Irish Lambs

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Introduction

Lamb carcasses are the key output from the sheep enterprise and should be the unit around which information on market requirements is focussed. Ultimately the consumer of meat is the constituency that places a value on this primary product and therefore producers deserve clear information about consumer requirements. There is a general consensus that consumers do not want to buy fat, and that excessive amounts of fat is a problem for sheep meat. This information can only flow via the chain from consumer to retailer to processor (abattoir) and the latter should be able to reflect this intelligence in the value placed on a particular carcass. There is certainly a case to be made that this idealised flow of information is not effective at present and thus not serving the long-term interests of the sheep sector. This is perhaps best exemplified by the scope for producers to simply increase carcass weight to maximise returns per carcass. This has clear implications for the quality of the 'meat' produced –it will contain significantly more fat- and the size of the joints offered to consumers. Is this what the consumer is willing to spend money on or is it undermining the future of the market?

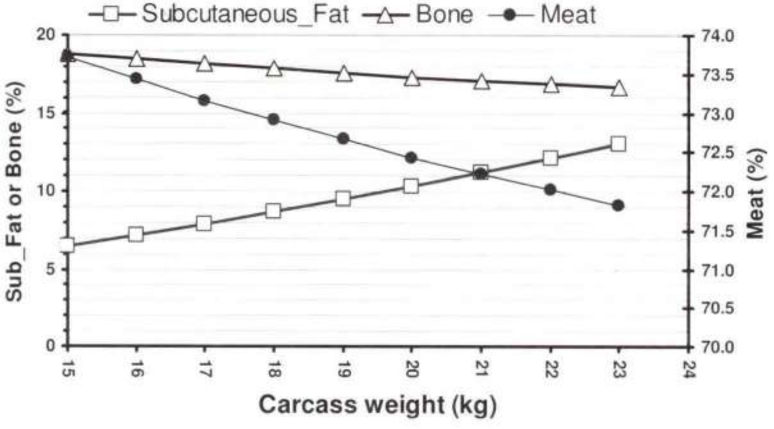
This paper will present observations on the nature and composition of the product as an aid to constructive dialogue about industry objectives.

Basic principles of carcass composition

The information summarised in Figure 1 provides a description of how carcass composition changes as lambs grow and carcass weight increases. As carcass weight increases the proportion of subcutaneous fat (i.e. fat on the surface of the carcass) increases steadily and the proportion of bone decreases. While consumers eat muscle plus some of the visible fat (subcutaneous and intermuscular) depending on their individual tastes, the term meat (i.e. the carcass minus the bone and subcutaneous fat) will be used as a reasonable approximation for what is consumed. The proportion of (chemical) fat in the meat also increases steadily as the carcass gets heavier, to the extent that as carcass weight increases from about 16kg to 22kg, the proportion of fat in the meat goes from 15g per 100g to 22g per 100g – an increase of 50% in the proportion of fat in the meat.

While it is possible to nutritionally manipulate the fat content, the consequences of increased carcass weight are inevitable, and everybody with an interest in maintaining the place of lamb in the basket of meat purchased by the consumer needs to recognise that people do not want to eat fat - what is required is just enough fat to ensure a good eating experience (tenderness and flavour). If it is agreed that this basic premise is correct then the producer deserves to have clear signals from the market that reflect this proposition or else it must be asked whether this premise is wrong!

Figure 1. Shows the relationship between carcass weight and the proportion of surface fat on the carcass (= subcutaneous fat), bone and meat (= carcass (bone + subcutaneous fat))



Carcass classification

Carcass classification refers to the description of carcass in terms of conformation (shape) and fat cover (including internal fat on the carcass in the kidney and pelvic areas). It is important to appreciate that classification does not inherently address the issue of carcass value. The basis for the sheep carcass classification is set out in EU Regulation 2137/92 and its objective was to improve market transparency. It was designed to provide information on the carcass attributes that allow the market valuation to be reflected back to the producer. This regulation has been implemented by export abattoirs and is monitored by the Department of Agriculture and Food.

The classification profile of more than 250,000 lamb carcasses classified by one Irish abattoir between April and December 2004 is summarised in Table 1. The lambs were from lowland flocks. This shows that the vast majority of lambs from lowland flocks are in three categories and the evidence suggests that very few carcasses are over fat, i.e. fat class 4 or 5. However, this is probably an overly optimistic interpretation, and it is suggest that the classification applied is not very severe on fat cover and that many class 3 carcasses are in fact over fat. The basis for this interpretation is that carcass weight has increased by at least 1kg since the mid 1990s, and when Teagasc staff classified around 6000 carcasses from commercial flocks during that period our classification yielded around 30 to 40% in the over-fat categories (Hanrahan, 1999). The evidence is summarised in Table 2, which also includes classification results for lamb classified at British abattoirs in 2000 and 2001 (MLC, 2002)

Table 1. Summary of carcass classification data for lambs at export abattoir in 2004

Conformation		Fat	
Class	Percent	Class	Percent
E	0.3	2	11.4
U	33.2	3	82.4
R	63.8	4	6.2
O	2.4	5	<0.1
P	0.3		

Most carcasses were either R3 (51.5%) or U3 (29.5%)

Table 2. Carcass fat class from observations on Irish and British lambs

Fat class	Source			
	IRL 93/96	IRL 97/00	IRL 04	Britain 00/01
2	10.3	6.7	11.4	18.6
3	58.3	51.4	82.4	71.9
4	25.1	33.5	6.2	5.1
5	5.5	8.4	<0.1	2.4
Average carcass weight	18.8	19.6	20.0	-

These findings reflect the inherent problem in comparing classification results – the standards used must be equivalent and this takes considerable effort. Obviously an objective (machine based) system is highly desirable. In the next section results from recent and on-going research on carcass composition is summarised to indicate the association between classification and composition.

Classification and composition

The relationship between fat classification and the percent fat in the soft tissue (i.e. carcass minus bone) from two recent studies in Teagasc is summarised in Tables 3 and 4. In both studies, the percent fat increased substantially as fat class increased from 2 to 3 to 4. The values in Table 3 are for carcasses classified by the Teagasc staff (using MLC standards) whereas the results in Table 4 are for lambs classified by staff at an export abattoir. The comparison of the carcass weight and percent fat strongly support the earlier proposition that the apparently satisfactory overall classification results for Irish lamb (Table 1) is too lenient in terms of fat percentage and should not be used to conclude that all is OK with the quality of Irish lamb at the point of slaughter.

Table 3. Results from chemical analysis of soft tissue (carcass minus bone) from 171 lambs classified using MLC standards (from study described by Hanrahan, 1999).

Fat class	Carcass weight (kg)	Percent fat
2	16.9	11
3	19.0	15
4	23.0	23

Table 4. Results of chemical analysis of soft tissue (carcass minus bone) from lambs based on abattoir classification (n = 56), (Hanrahan and Allen, unpublished data).

Fat class	Carcass weight	Percent fat
2	17.3	16.7
3	21.5	23.5
4	23.9	31.2

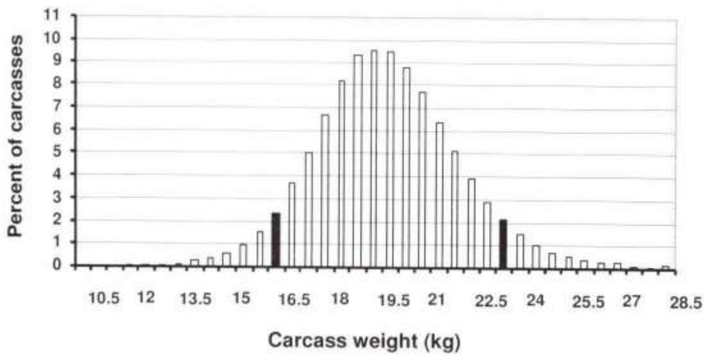
A similar association exists between conformation and fat percentage. Thus, as conformation goes from an 'O' to an 'R' the percent fat goes from about 17% to 30%; going from 'R' to 'U' is associated with another jump of about 8 percentage points.

Carcass weight

This attribute of the carcass can be objectively measured and, as shown in Figure 1 is clearly related to carcass composition and can thus provide objective information about the product. If the old, and very apt adage, that "*a lamb is only fit for slaughter once in its life*" is taken as a starting point, then given the relationship in Figure 1, it is necessary to look at variability in carcass weight. The variation in carcass weight at export plants is shown in Figure 2.

Close inspection of this evidence reveals that it takes a spread of 7kg to accommodate 90% of the carcasses. This is an enormous range! Data from research flocks, where lambs are drafted for sale using weight, and an assessment of finish - with the objective of avoiding over fat carcasses and getting an average carcass weight of about 18.5kg, the range in carcass weight is no more that 4 kg.

Figure 2. The distribution of carcasses by weight; the red bars mark the points between which 90% of all carcasses are found



Processors frequently express the view that carcass 'quality' is great in spring but deteriorates as the season progresses. This 'fact' is not clearly reflected in classification results as indicated in Figure 3. Yes, the proportion of U3 carcases declines from April to June, with a corresponding increase in proportion of R3, but the classification profile then remains essentially steady right through until December. However, there is another pattern that is evident over the season and this is shown in Figure 4. This shows the variability in carcass weight and how it changes over the season. In May and June the variability (measured here by the standard deviation within batches of lambs from a given supplier on a given day) is about 1.6kg, this increases steadily over the year; 1.8kg in July/September and around 2.0kg in October/November. It gets even worse in the December to February period.

Figure 3. The change in carcass classification between April and December (Over fat = Fat classes 4 and 5 combined)

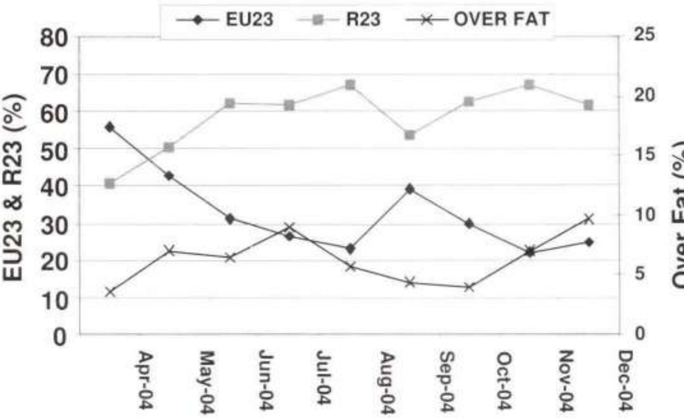
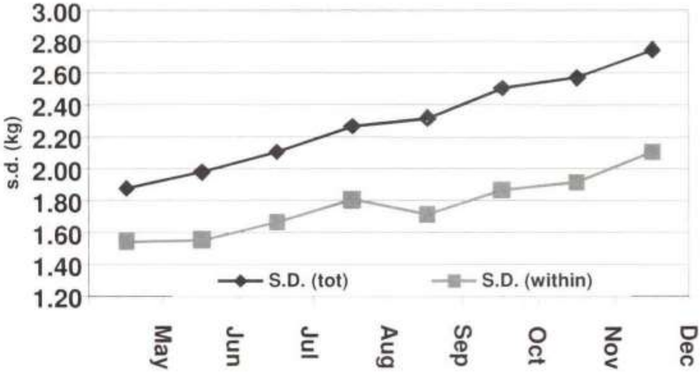


Figure 4. Variability (measured by the standard deviation of carcass weight), on the basis of lambs at the abattoir on a given day, among lambs from a given supplier (S.D. (within)) and among all lambs (S.D. (tot)).



Translating these statistics into the profile of carcass weight shows that the spread in carcass weight for a given supplier increases from ~5kg in May/June to ~6kg in July/September to ~7kg in October/November. It must be emphasised that this spread represents what the average supplier is sending on a given day! Factor in the variation among suppliers to get a picture of the carcass profile that must be marketed from a given abattoir on any given day... - examples of the spread in carcass weight within an abattoir on a given day are as follows:

7kg in May,
7.5kg in August
8.5kg in October
Over **9**kg in December

This makes effective marketing of the product very difficult (imagine the resulting variability in the size of joints and cuts) and processors need to address this issue or else make clear that it has no relevance to the price that they can obtain for the product and hence the price offered to the producer.

One factor that contributes to the increased variability is the pattern of lamb drafting for slaughter. The evidence for this is summarised in Table 5 and shows that in the early part of the season the interval between lamb drafts is around 10 days; this increases to over 3 weeks in June/July, 4 weeks in August/September and hits around 5 weeks in November/December.

Table 5. The number of days between drafting lambs from an average flock as the season progresses and the mean number of lambs per batch (based on over 250,000 records from one export abattoir in 2004)

Month	No. of days	Lambs per batch
April	9	15
May	12	20
June	16	22
July	19	25
August	25	29
September	28	28
October	28	29
November	35	28

Carcass weight and classification

Even allowing for the above concerns about the precise interpretation of classification, it is instructive to look at what happens as carcass weight increases. Evidence is presented in Table 6, which groups Fat classes 4 & 5 together as definitely over fat. Included also are the small number of ''E' carcasses with the 'U' category.

Table 6. Association between carcass weight and classification

Carcass weight range (kg)	Over fat	Conformation class U
14.0 to 16.9	0.2%	3.0%
17.0 to 19.9	1.5%	25.1%
20.0 to 22.9	6.5%	52.8%
23.00 to 25.9	15.5%	71.7%

The expected pattern is evident – as weight goes up the incidence of over-fat carcasses goes up and so does 'good' conformation. This reflects a well established aspect of sheep carcass classification systems – good conformation is associated with increased fatness.

Conclusions

The evidence presented in this paper shows the following:

As carcass weight increases the fatness of the product increases. An increase of one unit in fat class is associated with an increase in chemical fat by 1.5 times (e.g. from 11% to 15%).

The same relationship holds for conformation changes and the percent of subcutaneous fat.

The variability in carcass weight is excessive. The industry as a whole needs to reflect on this issue, and clear evidence is needed on whether solving this problem can deliver better returns to the serious producer.

Unfortunately, at the present time there is a grossly inadequate specification of what the market requires and thus an absence of consistent and clear signals to the producer (and researcher!). While this deficiency will require considerable effort to resolve, and the resolution will have to involve both producers and processors, the hope is that the evidence summarised in this paper will contribute to an informed debate on the issue.

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Efficient Sheep Production in a Subsidy Free Environment – Research from Athenry

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Introduction

Ireland has 4.26 million sheep (the fifth largest flock in the EU 25), accounting for approximately 5% of the total ewe number. In 2005 the output from sheep production was equivalent to €192 million, which was 3.9% of the Gross Agricultural Output. Since the implementation of the Mid Term Review (MTR) of the Common Agricultural Policy (CAP) sheep production is in the process of transition from an environment in which decisions were often subsidy driven to a market orientated, subsidy free system. With the decoupling of subsidy from farm production and the proposed reduction of tariffs in World trade, it is predicted that the Irish ewe flock will decline by up to 24%. Since the implementation of the MTR of the CAP on January 1 2005, ewe numbers have declined by 7.5%. Sixty eight per cent of flocks have less than 100 ewes with only 11% of flocks having greater than 200 ewes.

Prior to December 31 2004 (in subsidy driven systems of sheep production), the subsidy received equated to €1.43/kg carcass produced. To achieve a viable income from sheep production in the future, producers will have to increase flock size, increase output per labour unit, and improve production efficiency whilst at the same time obtaining a higher return from the market place to offset the loss of the €1.43/kg carcass in subsidy forgone. The aim of this paper is to highlight the potential savings, which can be made in the cost of sheep production based primarily on research studies undertaken at Teagasc Athenry.

What is the current output of lamb, and what is achievable?

Weight of lamb carcass output per ewe put to the ram but ultimately per hectare are the major factors affecting margins from sheep production. Recent studies undertaken at Athenry and Knockbeg have reported annual lamb carcass output of up to 500kg/ha (Table 1). These high carcass outputs were achieved from a combination of high stocking rate and high weaning rate. Currently a large proportion of flock owners are participants in the Rural Environment Protection Scheme (REPS), which limits potential stocking rate. Studies at Athenry involving outdoor year round grazing compatible with REPS, have shown that an output of 344kg lamb carcass per hectare is achievable (Table 1). Data from the National Farm Survey (Table 1) indicates that the national average output of lamb carcass on lowland farms is only about 197kg/ha, which is due to a low stocking rate combined with low number of lambs reared per ewe put to the ram. The output of lamb carcass achieved in research flocks in conventional and REPS compatible grass based systems were 150% and 80% greater than the national average.

Table 1. Achieved lamb output at Athenry and the national average output

	Athenry			National Average
	Conventional	Conventional	REPS	
Ewes/ha	16.5	14	10	8.3
Lambs reared/ewe	1.70	1.86	1.78	1.25
Lamb carcass output				
kg/ewe	31.3	35.3	34.4	23.8
kg/ha	494	494	344	197
	(Nolan and McNamara, 2002)	(Flanagan, 2000)	(Flanagan, 2000)	(Kinsella, 2005)

Improving Efficiency

Improvement in efficiency on farms is possible by exploiting changes in genetics, nutrition and management of the ewe flock.

Improvements in genetics

Whilst improvements in efficiency of sheep production due to breeding are slow, the changes are cumulative and permanent. Improvements in genetics are achievable through the ewe and the sire.

Ewe genotype

Weight of lamb sold per ewe joined to the ram is the major factor affecting profitability at farm level. Changing genetics is the cheapest and often the only method available to improve lamb output per ewe. A major study involving 2000 ewes was undertaken at Athenry to evaluate the impact of ewe genotype on lamb output. Eight sire breeds were mated to Scottish Blackface ewes and the female progeny were evaluated to determine the effect of ewe genotype on fertility, litter size and weaning rate (lambs reared per ewe joined to the ram). The results are presented in Table 2. Fertility is the proportion of sheep let to the ram that produce lambs. The Belclare X, Border Leicester X, and Scottish Blackface had the highest fertility whilst the Cheviot X and Galway X had the lowest. The Belclare X produced the highest litter size being 0.41 greater than Scottish Blackface and 0.18 greater than the Bluefaced Leicester X (Mule). The number of lambs reared per ewe put to the ram (weaning rate) provides an overall index of reproductive performance. Choice of ewe genotype altered weaning rate by 0.36 lambs/ewe and the value of lamb sales by €22/ewe put to the ram (based on 2005 lamb price). The Belclare X produced the highest weaning rate, being 0.16 greater than the mule (€10/ewe), and 0.34 (€22/ewe) greater than the Suffolk X. Currently the national flock consists of 45% Suffolk and Suffolk crosses.

The data presented in Table 2 clearly illustrate that total weaning rate can be increased dramatically by changing the ewe genotype. Use of Belclare in the first cross with the Scottish Blackface resulted in an extra 36 and 21 lambs being weaned per 100 ewes put to the ram relative to the purebred Scottish Blackface and Suffolk X, respectively. Furthermore increasing the proportion of Belclare genes in the ewe will increase the weaning rate further. Recent data from Athenry show that a weaning rate of 1.95 lambs per ewe put to the ram is achievable when using purebred Belclare ewes. As the litter size increases the proportion of ewes in the flock producing triplets increases. Some producers wish to avoid triplets, as they believe that they are difficult to finish. Recent data from this Research Centre have shown that lambs reared as triplets, using appropriate management, only require an additional 14 days to achieve similar carcass weights as lambs reared as twins.

Table 2. Effect of ewe genotype on reproductive performance

Ewe genotype	Fertility	Litter size	Weaning rate
Belclare x S. Blackface	0.94	1.89	1.54
Blue Leicester x S. Blackface	0.91	1.71	1.38
Border Leicester x S. Blackface	0.94	1.60	1.36
Suffolk x S. Blackface	0.91	1.65	1.33
Texel x S. Blackface	0.93	1.58	1.33
Galway x S. Blackface	0.83	1.63	1.20
S. Blackface	0.94	1.48	1.18
Cheviot x S. Blackface	0.86	1.51	1.11

(Hanrahan, 1994a)

More recent studies (Table 3) have shown that Belclare x Cheviot ewes have increased the number of lambs weaned by 15 and 20 per 100 ewes put to the ram relative to Blue Leicester x Cheviot and Suffolk x Cheviot ewes respectively. The Technology Evaluation and Transfer (TET) project which was initiated in 2001 by Teagasc on 40 sheep units throughout Ireland for a three year period clearly illustrates that flocks which comprised predominantly (but not solely) Belclare X ewes had higher weaning rates of 0.08 and 0.24 relative to flocks which were either Mules or Suffolk X.

In recent years there has been interest in the use of the Vendeen breed. A major study was undertaken on a large commercial farm (1140 ewes) by Teagasc to evaluate the effects of Vendeen X and Belclare X ewes on prolificacy. The ewes had been bred on the farm as flock replacements and performance was recorded over a three year period. The data from the study showed that the Belclare X ewes produced larger litters and number of lambs born alive per litter. For the Belclare X and Vendeen X ewes litter size was 2.15 and 1.95 lambs/ewe and number of lambs born alive were 2.00 and 1.81 lambs/ewe respectively. Therefore the major effects of ewe genotype on weaning rate observed in many studies at Athenry have been confirmed at farm level.

Table 3. Effect of ewe genotype on reproductive performance

Ewe genotype	Litter size	Weaning rate
Belclare x Cheviot	1.87	1.62
Blue Leicester x Cheviot	1.78	1.47
Suffolk x Cheviot	1.72	1.42

(Hanrahan, 1997)

Terminal sire breed

Using the payment schemes currently in use by the majority of export meat plants, growth rate is the most important characteristic when choosing a terminal sire breed. Increased growth rate enables lamb to be finished earlier, reducing feed costs whilst at the same time avoiding lower prices as the season progresses.

Most processors offer bonuses of 6c/kg for U grades. Assuming a 20kg carcass, the bonus of 6c/kg is worth €1.20, which is equivalent to either 0.36kg carcass or the additional weight gain achieved by keeping the lambs approximately 4 days longer on your holding prior to slaughter. However selecting sire breeds for improved conformation is unlikely to increase the proportion of U grades by as much as 20%, an increase of this magnitude is equivalent to 1.2c/kg carcass of all lambs marketed. Furthermore it should be noted that breeds with improved conformation characteristics tend to have lower growth rates, therefore being older at the point of marketing. Consequently increased feed costs will accrue whilst at the same time lamb price is likely to decline as the season progresses. Therefore whilst conformation is a frequently discussed topic in the industry, the reward is relatively small.

A major study at Athenry has evaluated the effect of nine sire breeds on progeny performance (Table 4). Choice of sire breed altered weaning weight by up to 2.5kg and days to slaughter by up to 20 days. The progeny of Suffolk rams were heaviest at weaning and earliest to reach slaughter. Relative to the Suffolk, the Charollais and Texel progeny required an additional 5 and 9 days to reach slaughter weight respectively. Progeny from the other sire breeds, required between 12 and 20 days relative to progeny from the Suffolk to reach slaughter. The Beltex produced progeny with the best conformation followed closely by Ile de France, Suffolk, Charollais, Texel and Vendeen. Beltex had the highest kill out proportion followed closely by Ile de France, Charollais and Texel.

Due to interest within the industry in the Vendeen as a terminal sire, a further evaluation of the breed, in direct comparison with the Belclare, was undertaken on a large commercial farm (1140 ewes). At weaning, lambs sired by Vendeen and Belclare rams weighed 31.9 and 31.0 kg respectively, similar to the differences observed in the large breed study undertaken at Athenry, which concluded that lambs sired by Vendeen and Belclare rams produce carcasses of similar characteristics at the same age.

Table 4. Effect of terminal sire breed on progeny performance

Sire breed	Weaning wt. (kg)	Extra days to finish relative to the Suffolk	Kill-out (g/kg)	Carcass	
				Conformation[1]	Fat[2]
Suffolk	31.8	-	438	3.3	3.3
Charollais	31.0	5	449	3.3	3.2
Texel	30.6	9	446	3.3	3.2
Beltex	30.5	16	446	3.5	3.3
Ile de France	30.2	20	452	3.4	3.4
Rouge de l'Quest	30.2	12	438	3.2	3.2
Vendeen	30.0	14	445	3.3	3.2
Bleu du Maine	29.4	18	435	3.2	3.1
Belclare	29.3	15	442	3.1	3.3

[1]EUROP scale where E=5, U=4, R=3, O=2, P=1.
[2]1 = leanest; 5 = fattest
(Hanrahan, 1999)

Recently the Suffolk, Texel and Beltex terminal sire breeds have been evaluated in Northern Ireland (Table 5). Similar to previous work at Athenry, the data from Northern Ireland confirm that relative to the Suffolk, progeny from Texel sires take slightly longer to finish whilst progeny from the Beltex require an additional 22 days to achieve similar finish and carcass weight. However Beltex progeny had improved conformation and increased kill out proportion in agreement with Teagasc data.

Table 5. Effect of terminal sire breed on carcass characteristics of lambs slaughtered at Fat class 3

	Sire Breed		
	Suffolk	Texel	Beltex
Weaning weight (kg)	37.5	36.6	34.7
Age at slaughter (days)	156	159	177
Kill out (g/kg)	434	456	459
Carcass characteristics			
Weight (kg)	19.2	19.5	19.4
Conformation[1]	3.0	3.3	3.5

[1]EUROP scale where E=5, U=4, R=3, O=2, P=1

(Carson *et al.*, 2004)

Currently Suffolk and Suffolk X account for approximately 45% of the national ewe flock. Data from Athenry has concluded (Table 6) that when choosing a terminal sire breed for Suffolk X ewes, use of Texel and Charollais rams tends to produce heavier progeny at weaning, which finish earlier relative to progeny from Suffolk rams. This is probably due to reduced hybrid vigour when Suffolk rams are used on Suffolk X ewes.

Table 6. Effect of sire breed on the performance of progeny from Suffolk X ewes

	Sire breed	
	Suffolk	Texel
Weaning weight (kg)	33.8	34.2

(Hanrahan, 1994b)

The data from these studies clearly illustrate that when choosing a terminal sire, the only breeds which merit serious consideration are the Suffolk, Charollais and Texel. The other breeds produce progeny which take considerably longer to reach market and with little or no benefit in carcass characteristics. Furthermore, it is of interest to note, that the Belclare breed which was developed for its maternal characteristics resulted in carcasses of similar characteristics to the other breeds and take only 15 days longer to finish relative to the Suffolk, similar to the results of the five of the other eight breeds evaluated. In terms of cost of lamb production, terminal sire breed has a small impact on production efficiency altering the cost of production by about 7c/kg carcass produced, or €1.40/lamb.

Nutrition of the ewe and her progeny

Plane of nutrition can be altered at any stage during the annual cycle of the ewe or during the life-time of the progeny and will have an immediate effect on performance.

Nutrition in late pregnancy
The nutrient requirement of the ewe increases dramatically in late pregnancy due to the rapidly growing foetuses. The weight of the foetus increases by 85, 50 and 25% respectively during the last 8, 4 and 2 weeks of pregnancy. During the last six weeks of pregnancy the energy requirements of ewes carrying singles, twins and triplets increases by 40, 60 and 70% respectively. Currently in Ireland a large proportion of ewes are housed in late pregnancy and offered either grass silage or hay *ad-libitum* as the sole forage. Concentrate supplementation is required in late pregnancy to meet the rapidly increasing nutrient requirements whilst at the same time food intake capacity is declining. The decline in food intake is due to the rapidly growing foetuses reducing available space within the abdominal cavity for the digestive system and its contents. The level of concentrate supplementation required depends on the forage feed value and the expected litter size.

Forage feed value
The major factors affecting the feed value of grass silage for sheep are digestibility and chop length. The effects of silage chop length on the performance of finishing lambs are presented in Table 7. Reducing the chop length dramatically increased silage intake resulting in improved animal performance as measured by daily liveweight gain and final carcass weight. These data clearly illustrate that chop length has a major effect and that the shorter the chop length the higher the silage intake.

Table 7. The effect of silage chop length on the performance of finishing lambs

	Harvester type			
	Single Chop	Double Chop	Precision	
			Long	Short
Liveweight gain (g/d)	40	53	85	151
Carcass weight (kg)	16.6	18.5	20.0	22.7

(Fitzgerald, 1996)

Digestibility (DMD) is the most important factor affecting silage feed value as it impacts on both the metabolisable energy concentration of the forage and also on its intake characteristics. Increasing silage digestibility increases feed value and reduces the level of concentrate supplementation required during late pregnancy. The impact of silage digestibility and chop length on concentrate requirement of twin bearing ewes during late pregnancy are illustrated in Table 8. Increasing levels of concentrate are required as silage digestibility declines and also as the chop length increases. It can be assumed that the intake characteristics of single chop and big bale silages are similar if ensiled under identical conditions. The data clearly illustrate that silage digestibility and chop length can impact on the quantity of concentrate required during late pregnancy by up to 400%. Each 5 unit increase in silage digestibility offered during a standard winter housing period improves efficiency of lamb production by 16c/kg carcass through a combination of reduced concentrate requirement in late pregnancy and better nutrition in mid pregnancy which increases lamb birth weight and subsequent performance (heavier weaning weight and earlier sale date).

Table 8. Effect of silage chop length and digestibility on concentrate requirements of twin bearing ewes in late pregnancy (kg/ewe)

Harvester Type	Silage DMD (%)		
	79	72	64
Precision	8	12	20
Single chop / big bale	12	20	30

Litter size

Litter size has a major influence on the level of concentrate required in late pregnancy. As litter size increases concentrate input must increase to meet additional nutrient requirements. For the 72 and 64 DMD silages in Table 8, concentrate feed levels can be reduced by 11 kg/ewe for single bearing ewes and should be increased by 7 kg/ewe for triplet bearing ewes during the last 6 weeks of pregnancy.

Protein requirements increase dramatically during the last 4 weeks of pregnancy. Consequently, during this period the crude protein level in the concentrate should be 18% for ewes offered moderate to high feed-value silages. However, for ewes offered low feed-value grass silage or hay the protein level of the concentrate should be increased to 20%.

Concentrate price

Concentrate price can vary dramatically. High quality concentrate can be produced cost effectively by mixing a blend of straights together with a proprietary sheep mineral and vitamin mixture and offered as a course ration. Examples of cost effective high quality concentrate mixtures are presented in Table 9. In late pregnancy good quality protein sources are desirable. Soyabean is a high quality protein source and should be included in all supplements offered to sheep in late pregnancy. Replacing 5% of barley in these mixes with 5% soyabean meal alters the crude protein concentration by 2%. Concentrate price is frequently discussed in the sheep industry. However, changing the price of concentrate by €30/tonne only alters efficiency of lamb production by 2c/kg lamb carcass produced.

Table 9. Simple concentrate mixes for sheep

(1)	40% barley, 35% beet pulp, 25% soyabean meal + 25 kg mineral/vitamins (*Crude protein = 18%)*
(2)	30% barley, 30% citrus pulp, 10% maize gluten, 10% distillers, 20% soyabean + 25 kg mineral/vitamins (*Crude protein = 18%)*

Grassland management

When all the costs of production and utilisation rate are considered, grazed grass is not a cheap feed to produce. Recent costings (Table 10) demonstrate that whilst grass is the cheapest forage to produce, it is only 6 to 31% cheaper than ensiled forages. For example, maize when grown under the complete-cover plastic mulch system can now be produced and fed to farm animals at a similar cost to grazed grass. Furthermore, three cut silage only costs 16% more than grazed grass.

Table 10. The relative costs of forage production (all production costs including land charge)

Forage	Cost (€/t DM consumed)	Relative Cost
Grazed grass	104	100
3-cut silage	121	116
4-cut silage	136	131
Fermented whole crop	126	121
Maize - no plastic	134	129
- plastic	110	106

(after Keady *et al*, 2002)

Forage Cost (€/t DM consumed) Relative Cost Grazed grass 104 100 3-cut silage 121 116 4-cut silage 136 131 Fermented whole crop 126 121 Maize - no plastic 134 129 - plastic 110 106 (after Keady *et al*, 2002)

In mid season fat lamb production, the forage component of the diet consists primarily of grazed grass. Additional feeds offered if required, are likely to be concentrate (€260-350/t dry matter), which is 300% or 690% more costly than grazed grass when all grass production costs or cash costs are included respectively. Consequently it is essential to increase daily performance from grazed grass to reduce production costs and enable lambs to finish earlier whilst avoiding price falls in the market due to late finishing. Many studies at Athenry have been undertaken to determine the optimum level of performance from mid season flocks at pasture. During the grass growing season daily grass growth rates vary dramatically, e.g. 10, 40, 90, 50, 60, 30 and 20kg DM/hectare/day for March, April, May, June, July, September and October respectively. At the same time the demand of the flock varies as the lamb grows pre weaning, whilst post weaning ewe requirements decline. At Athenry, sward height has been used to manage grassland. The impact of sward height on lamb performance pre weaning and post weaning are presented in Tables 11 and 12 respectively. Increasing sward height to 6cm during the pre-weaning period increased animal performance. However increasing sward height had no further beneficial effects on animal performance. However lax grazing pre weaning resulted in swards that had stemmy, low-digestibility herbage later in the season and consequently poor lamb performance post weaning. Increasing sward height to 9cm in the post weaning period increased animal performance. From numerous studies, the target sward-height to achieve optimum levels of performance are 5, 6, 7, 8 and 9cm in the months of April, May, June, July, August and September respectively. Also to maintain good performance at pasture it is essential to practice an effective parasite control regime.

Table 11. Effect of sward height on lamb performance in May and June

Sward height (cm)	Liveweight gain (g/d)
4	267
6	306
9	315

(Grennan and O'Riordan, 1996)

Table 12. Effect of sward height on lamb performance post weaning

Sward height (cm)	Liveweight gain (g/d)
5	115
7	141
9	162

(Grennan and O'Riordan, 1996)

Creep feeding

There is a lot of interest in creep feeding lambs presumably with the intention of finishing lambs earlier. The response to creep feeding depends on grass availability. The results of a number of studies at Athenry undertaken to evaluate creep feeding are summarised in Table 13. Creep feeding increased weaning weight regardless of sward height. However, it should be noted that creep feeding 300g concentrate/lamb/day on the low swards resulted in the same level of performance as lambs grazing the high swards with no creep feed. Therefore creep feeding replaced good grassland management. Lambs offered 300 and 600g creep/day consumed 30 and 50kg concentrate respectively. For lambs offered creep feed, 14kg concentrate was required to produce each additional 1kg of carcass weight, which is a poor food conversion ratio. Creep feeding reduced age to slaughter by 28 days. However increasing grass height from 5 to 6cm reduced age at slaughter by 13 days, half the effects of feeding 32.5kg creep/lamb.

Table 13. Effect of creep feeding and sward height on lamb weaning weight (kg)

	Creep feed (g/lamb per day)					
	Low sward height (5cm)			High sward height (6cm)		
	0	300	600	0	300	600
Weaning weight (kg)	31.4	34.3	36.9	33.7	36.7	37.5
Drafted at weaning (%)	7.3	20.7	42.8	20.4	41.2	53.7
Age at sale (days)	167	140	125	154	126	118
Creep intake (kg)	0	32.5	52.9	0	27.5	46.0

(Grennan and McNamara, 2005)

Although creep feeding enables animals to be drafted at a younger age (and most likely at a higher price), the question often asked is "does it pay"? Assuming market price conditions that prevailed in 2004 and 2005, lamb price declined from €3.54 in early July to €3.10/kg carcass in late October, the period when the majority of mid season fat lamb is marketed. The effect of creep feeding on carcass value of the March born lambs relative to the carcass value of lambs receiving no creep (using the prevailing market prices of 2004 and 2005), and allowing for the cost of creep consumed by the lambs at concentrate prices ranging from €150 to €325/t is presented in Table 14. The data clearly illustrates that regardless of grass height, offering creep to lambs, which enabled slaughter at a younger age did not cover the cost of the creep within a concentrate price range from €150 to €325/t. It is also observed that increasing sward height from 5 to 6cm increased carcass value by €2.50/head. Whilst no allowance has been made for the additional grass required to feed the lambs without creep feed, the grass cost will have little impact on the economics of production. Many sheep farms in Ireland are moderately stocked which enables greater production of grass at little extra cost. Prior to slaughter, 40kg lambs consume approximately 1kg grass DM/head/day, requiring an additional 27kg DM to finish. Whilst the total cost of grass production is €104/t DM (Table 10) the cash cost is €44/t DM. Consequently, the additional grass required without creep feeding would cost €1.18. Even allowing for grass cost, creep feeding concentrate at a cost greater than €175 does not break even. Furthermore the producer requires additional returns to cover the cost of purchase of feeders, concentrate storage and labour. Also if lambs are fed creep to finish early, the producer must establish what, if any, is the opportunity cost of the grass remaining? It is concluded that creep feeding mid season lamb does not give an economic return.

Table 14. Effect of creep feeding on carcass value (€) of March born lambs, after cost of creep, assuming market conditions of 2004/05 relative to lambs receiving no creep at two sward grazing heights (€/carcass)

	Sward height (cm)			
	5		6	
Creep feed level (g/day)	300	600	300	600
Concentrate price (€/t)				
150	-0.56	-0.55	-0.45	-2.15
175	-1.37	-1.87	-1.14	-3.30
200	-2.19	-3.19	-1.83	-4.45
225	-3.00	-4.51	-2.51	-5.60
250	-3.81	-5.84	-3.20	-6.75
275	-4.62	-7.16	-3.89	-7.90
300	-5.44	-8.48	-4.58	-9.05
325	-6.25	-9.80	-5.26	-10.20

Management practices

Changes in some farm management practices can increase efficiency of lamb production at no extra cost.

Finishing male lambs as rams

Traditionally male lambs were castrated to facilitate management post weaning when lambs are reaching sexual maturity. However there is plenty of evidence from other species, e.g. beef cattle, that finishing the male progeny entire increases growth rate, food conversion efficiency and produces leaner carcasses. A major study was completed at Athenry to evaluate the effect of finishing male lambs entire (as rams) on animal performance. The results are presented in Table 15. Lambs finished entire were 1.8kg heavier at weaning, produced leaner carcasses and were slaughtered 16 days earlier than lambs which were castrated shortly after birth. The data clearly show that finishing male lambs entire increases performance. Finishing lambs entire, improved efficiency by 13c/kg for male lambs or by 7c/kg if all progeny from the flock are slaughtered, similar to the response obtained from choice of terminal sire breed. However it should be noted that post weaning, ram lambs should be managed separately from ewe lambs, otherwise, the potential benefits in growth rate will be foregone as young rams will be very active in the presence of females. Furthermore if the current production system is not capable of delivering the majority of lambs to slaughter by late August, then the potential advantages of leaving lambs entire is reduced and product quality may be compromised.

Table 15. Effects of finishing male lambs entire on animal performance

	Treatment	
	Castrated	Entire
Weaning weight (kg)	29.9	31.7
Carcass weight (kg)	18.2	18.1
Kill out (%)	44	43
Fat score[1]	3.1	2.9
Sale date	24 August	8 August

[1] Fat score 1 to 5

(Hanrahan, 1999)

Winter shearing

All sheep must be shorn once per year. At current wool price and shearing cost, the value of the fleece does not cover the expense of shearing. A recent study at this Research Centre has evaluated the impact of shearing housed ewes in mid pregnancy or grazing out doors all winter and lambing at pasture on subsequent lamb performance. Ewes that were shorn had their fleeces removed in mid December. All sheep lambed in early March. The effects on lamb performance are presented in Table 16. Shearing housed ewes had the same impact on lamb birth weight and subsequent performance as outwintering on grass and lambing outdoors. Shearing increased lamb birth weight by 0.6 kg/lamb and weaning weight by 2.4kg relative to lambs from ewes that were housed but not shorn. The data from this study illustrate, that shearing housed ewes increases subsequent lamb performance such that they are fit for slaughter two weeks earlier than lambs from housed ewes that were unshorn. The increased weaning weight due to winter shearing improves efficiency of lamb production by 15c/kg carcass. Furthermore shearing facilitates management and reduces fixed costs as space requirements at the trough and in the house are reduced.

Table 16. The effects of shearing housed ewes and outdoor lambing on subsequent lamb performance

	Ewe treatment		
	Indoors unshorn	Indoors shorn	Outdoors Unshorn
Lamb birth weight (kg)	4.2	4.8	4.9
Liveweight gain (g/d) (birth – weaning)	288	307	312
Weaning weight (kg)	32.4	34.8	35.2

(Keady et al, 2006)

Condition score

Condition score is a method of accessing the fatness or condition of animals. It is assessed by handling the ewe over and round the backbone, in the area of the loin behind the last rib. Condition score is based on a scale from one to five where one and five represent extremely thin and fat ewes respectively. In dairying and suckler cow production, condition score is a management tool used in late lactation, at calving and during the breeding season to monitor cow condition score change. In sheep production the most important time to have the ewes in the optimum condition is at the time of joining the rams with the flock.

Teagasc has studied the effects of condition score of the ewes at the beginning of the breeding season on subsequent flock productivity. Work undertaken on 40 commercial farms as part of the TET project concluded that each one unit increase in condition score within the range of 2.5 to 4.5 increases ewe liveweight by 12kg and lambs weaned per ewe joined by 0.10.

Is there a viable future for sheep production?

Many different aspects of mid season fat lamb production has been discussed in the current paper. 'Maximum potential' improvements in efficiency on Irish sheep farms, and those 'achievable in practice' are presented in Table 17. The data demonstrate that if all the individual potential improvements in efficiency for genetics, nutrition and management of the ewe and lamb were achieved, the cost of production could be reduced by up to 132c/kg carcass. However, whilst all of the individual improvements are possible, they are not all cumulative and consequently are not possible for every lamb finished. Nonetheless, on most farms it should be possible to achieve half of the 'potential in practice improvements' in efficiency. Therefore improvements in efficiency could reduce the cost of production by up to 66c/kg carcass. Average lamb price for 2004 was €3.66/kg carcass. In addition €1.43 was received in subsidy per kg of lamb carcass produced. Consequently, even allowing for an improvement in efficiency of 66c/kg lamb carcass produced, the producer would require €4.43/kg carcass to maintain the income received in 2004 prior to implementation of the Mid Term Review of the Common Agricultural Policy.

Table 17. Opportunities to improve efficiency and profitability in sheep production

	€ / head		
	Maximum Potential	Potential in Practice	Carcass (c/kg)
Ewe genotype	22	13	48
Grassland	10	5.0	26
Silage	7.5	3.20	16
Winter shearing	2.9	2.9	15
Condition score	6	3	11
Entire progeny	2.5	1.3	7
Terminal sire breed	3.0	1.4	7
Concentrate	0.6	0.4	2

It is of interest to note from Table 17, that two of the most discussed topics by sheep producers, namely terminal sire breed and concentrate price, have the smallest impact on improving efficiency. The factors that have the greatest impact on efficiency are ewe genotype, grassland management, winter-shearing and high quality grass silage.

Conclusions

It is concluded that: -

Improvements in efficiency pre farm gate of up to 66c/kg carcass are possible.

The major factors, in order of importance, to improve efficiency pre farm gate are as follows

- Increasing litter size. Use Belclare or a breed with similar genetic merit.
- Good grassland management. Use sward height as a management tool.
- Winter shearing of housed ewes to reduce age at slaughter of the progeny.

- Produce high quality grass silage (greater than 75%DMD) for feeding housed ewes in mid and late pregnancy.
- Finish male lambs entire provided they are offered a good plane of nutrition.
- Use a mixture of straights as supplements to reduce concentrate cost.
- Choice of terminal sire breed. Suffolk, Charollais, Texel and Belclare are probably the only breeds that merit serious consideration.
- Creep feeding does not provide a return to the producer of mid season fat lamb, even allowing for earlier drafting and assuming market price changes during 2004 and 2005.

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Breeding Quality Cattle

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Introduction

Breeding is one of the most effective means of increasing the profitability of beef farming. However, in order to increase profit from beef breeding, structures and systems must be put in place to that will allow;

The accurate collection of relevant beef cattle breeding data;
The calculation of genetic indexes that will allow the best animals be selected for breeding;
A breeding program that ensures the best animals are used throughout the cattle breeding industry.

These areas have been the major focus of the Irish Cattle Breeding Federations work over the past 3 years, from the launching of Animal Events in beef herds (January 2004) to the imminent release of the new Total Beef Indexes and new breeding programs for Irish beef farmers. This paper is a summary of work over the past 3 years.

1. Accurate collection of relevant beef cattle breeding data

<u>Quality & Profit</u>

According to the Cambridge English dictionary the definition of quality & profit are as follows:

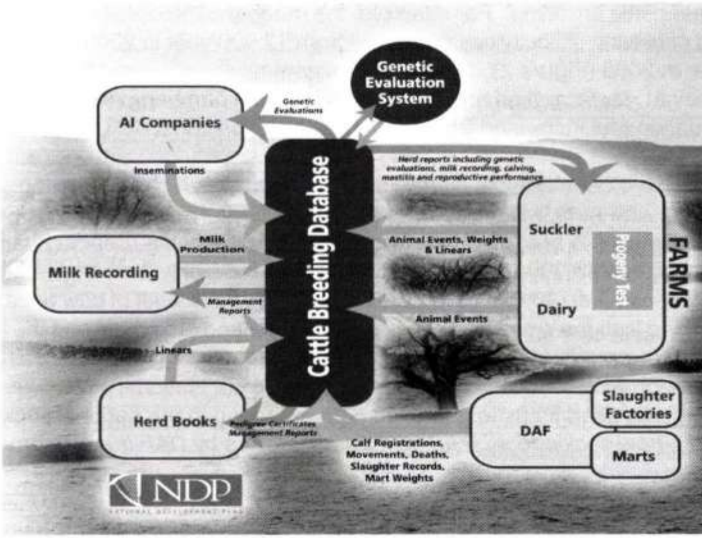
- *Quality* - how good or bad something is, a high standard.
- *Profit* - money that is earned in trade or business, especially after paying the costs of producing and selling goods and services.

Profit is the 'all-encompassing' word reflecting the essential deliverables for Irish beef farmers. However, if we think of quality in the context of 'quality maternal replacements' as well as 'quality weanlings' then 'quality & profit' are linked. In establishing the Irish Cattle Breeding Federation database, ICBF have been focused on collecting relevant data on all of the traits linked to profitable beef production, that is, traits associated with calving, weaning, slaughter & maternal.

<u>The ICBF cattle breeding database</u>

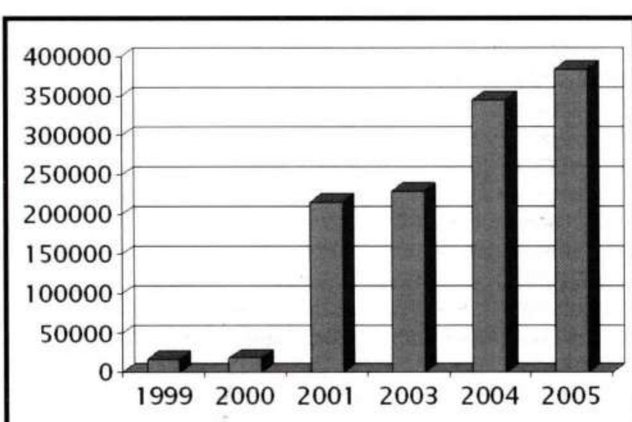
The cattle breeding database was first launched on beef farms in January 2004. Since then it has grown steadily, with some 15,000 suckler beef & 15,000 dairy herds now contributing to the database, totalling about 1 million calf births (Figure 1).

Figure 1. Overview of the ICBF cattle breeding database



Farmers involved in the cattle breeding database record their birth records through Animal Events, a simple and easy to use system that allows farmers record all of the data required for EU passport application, as well as pedigree registration and genetic evaluations. In addition, to having a simple system for recording data on-farms, the database is also linked to the many other industry systems that are also collecting beef cattle data, e.g., factory and mart data. ICBF has an excellent relationship with these various organisations, ensuring that valuable cattle breeding data (e.g., weights, conformation & price/kg) is collected at minimal cost and hassle for farmers and the industry.

Figure 2. Increase in number of calving performance records (1999-2005)



These initiatives have resulted in a major increase in the quantity and quality of data available for beef cattle breeding. For example, the number of records available for the genetic evaluation of calving difficulty has increased from 12,000/year in 2000 to some 380,000 collected/year in 2005 (Figure 2). Similar improvements are apparent for other traits such as carcass weight, conformation and fat score, where the number of records available for genetic evaluation has increased from 15,000 in 2002 to almost 440,000 in 2006.

Whilst there have been notable improvements in traits such as calving and carcass, problems still exist with traits linked closely to the sucker herd, i.e., maternal traits. For example, a recent analysis of ¾ bred suckler cows involved in the cattle breeding database has indicated that of the 240,000 cows involved in the database only 29% have a known sire, and only 60% of these (i.e., 46,000 cows) are AI bred. This low level of cow ancestry recording (29%), coupled with the small average herd-size in Ireland (15 cows) and the low heritability of these traits (generally about 5%) makes the job of evaluating maternal traits very difficult. Given the importance of suckler herd improvement to our National beef industry, it is critical that we give increased focus to improved data recording in our national suckler herd. *The launch of the new suckler cow scheme for beef farmers by DAF is a welcome step forward in this regard.*

2. Calculation of genetic indexes that allow identification of the best animals for breeding

Data and genetic indexes

The second stage in a beef improvement program is to ensure that the data is summarised in a simple way that will easily allow farmers use the information to select animals for breeding (e.g., AI bulls, stock bulls and cows for breeding replacement). Given the number of traits for which data is now collected (some 60 across calving, slaughter, Tully, linear type & maternal), this is no small task and relies on a combination of powerful statistical programs to account for non-genetic differences between animals in their observed performance (e.g., level of feeding, age and breed of dam) and then economic models to weight the traits based on their contribution to beef profit. The final end-product is an economic index (or profit index), that allows farmers establish the increased profit from each breeding decision. In total, 5 economic sub-indexes have been identified for beef farmers, covering each of the key breeding decisions; calving performance (dairy & beef), breeding calves for export, breeding calves for slaughter in Ireland & breeding maternal replacements (Table 1).

Bulls are then compared on the basis of their €-value for each sub-index. Therefore a bull that has a BPSI value of €150 will leave €100 more profit at slaughter than a bull with a BPSI value of €50. This represents a difference in final slaughter value of some €0.30/kg. In addition to the above five sub-indexes, animals can also be compared on the basis of their total beef value (or total beef EBI). This figure reflects a combination of where an animal's genes may appear within the industry (based on the % of animals that are exported, slaughtered and/or appear as maternal replacements). It is anticipated that, in the future, all bulls will be ranked on the basis of total beef EB, with farmers then able to choose, individual animals based on their strengths and weaknesses for various traits.

Do the indexes work?

One of the key questions asked by beef farmers, is do the new indexes work, and as a beef farmer can I use the indexes to increase profit?

Table 1. Summary table of the five sub – indexes linked to profitable beef production, including the component traits

Index	Trait		%	Explanation
BPSI (€) Beef Production Sub - Index	Carcass Weight	(Kgs)	55%	This Sub-Index will estimate how good a bull is at producing progeny with high value carcases.Bulls that are producing cattle that have a high carcase weight for age, good conformation at kill out and good lifetime feed efficiency will score highly.
	Weaning Weight	(Kgs)	20%	
	Carcass Conformation	(Grade)	12%	
	Dry Matter Intake	(Kgs)	8%	
	Carcass Fat	(Grade)	5%	
WCSI (€) Weaned Calf Sub - Index	Weaning Weight	(Kgs)	31%	This Sub-Index will estimate how good a bull is at producing high value weanlings for sale. Suckler farmers who are selling their weanlings should look more closely at bulls in this Sub Index.
	Calf Quality	(€)	69%	
BCSI (€) Beef Calving Sub - Index	Calving Difficulty	(%)	46%	This Sub-Index puts a direct cost on calving problems estimated for each bull when used in a Suckler Herd. It puts a direct cost on calving problems estimated for each bull. It takes into account calving difficulty, gestation length and mortality.
	Gestation Length	(Days)	28%	
	Calf Mortality	(%)	27%	
DCSI (€) Dairy Calving Sub - Index	Calving Difficulty	(%)	35%	This Sub-Index puts a direct cost on calving problems estimated for each bull when used in a Dairy Herd. It is very similar to the beef calving index, except that the economic impact of using a "difficult" calving bull on the dairy herd is much higher.
	Gestation Length	(Days)	55%	
	Calf Mortality	(%)	10%	
MSI (€) Maternal Sub - Index	Cow Survival	(%)	14%	This Sub-Index is to be used where a suckler farmer is choosing a bull to breed replacements from. Unfortunately information on this sub-index is not yet complete due to lack of ancestry & performance data on our national suckler herd.
	Calving Interval	(Days)	20%	
	Age at First Calving	(Days)	11%	
	Maternal Calving Difficulty	(%)	14%	
	Maternal Weaning Weight	(Kgs)	39%	
	Cull Cow Carcass Weight	(Kgs)	2%	

Table 2. Comparison of top & bottom 5 bulls for 6 beef breeds

	Index	Pred. differences			Age @ rec		Raw data		
	BPSI	Cwt	Conf	Wwt	Cwt	Wwt	Cwt	Conf	Wwt
Top bulls	€94	28	2.2	6	660	235	352	8	317
Bottom bulls	-€5	-1	1.3	-17	694	246	300	6	250

Looking at the performance of the top and bottom AI sires for each of the six main beef breeds (based on Beef Performance Sub Index – Table 2), indicates that the progeny of the high index sires had higher carcass weights (+52kg), better conformation grades (almost 1 point) and higher weaning weights (+67kg) based on raw data. In addition, these levels of performance were achieved at younger ages compared to the lower index sires (-34 days for carcass weight and -11 days for weaning weight). After accounting for differences due to environment and management, the genetic differences in favour of the high index bulls is +29kg carcass weight, +1.1 conformation score and +23kg weaning weight, representing a difference in beef profit of €99 per animal slaughtered. Similar results are available for each of the other sub-indexes, and total beef EBI, indicating that farmers can have confidence in the new indexes to increase profit from breeding.

Publication of the new indexes

Information is already available on 4 of the sub-indexes outlined in Table 2; calving (dairy & beef), export & slaughter. Work on the final sub-index (maternal) and hence total beef EBI is continuing and expected ahead of the winter 2006 season. Farmers can view the indexes for all relevant traits on the ICBF website (http://www.icbf.com) or in AI brochures for AI bulls. The key thing to note regarding these new indexes is that there are large differences within breeds on how much profit a given bull will leave at calving, slaughter, weaning or as a maternal replacement compared to another bull. The simple advice to beef farmers is that they should start to use the indexes immediately to help improve the profits from their beef enterprises.

In addition to EBI's for AI bulls, new Beef EBI reports will be posted to herd-owners. These reports will include for the first time, key information on maternal traits and total beef EBI, in addition to information on calving, export & slaughter. Again, herd-owners should use the new indexes to identify the cows and bulls that will leave more profit. In addition the reports will provide summaries by breed and age group to allow herd-owners benchmark the genetic merit of their herd, relative to other herds for these new indexes.

3. A breeding program that ensures the best animals are used widely throughout the cattle breeding industry

<u>Increasing genetic gain</u>

The current level of genetic gain in the national beef herd is €2/cow/year, which is about 10% of what could be achieved from an optimal program (€18/cow/year). Achieving this level of genetic gain could generate an additional €16 million/annum for Irish beef farmers and the beef industry. Achieving this level of gain would require a major up-scaling in progeny testing efforts, from the current 10 bulls/year (fully tested) to some 100 bulls/year. As a result of these potential benefits (and costs), ICBF and DAF are currently investigating options for a new beef progeny test program, which would have a combination of industry and government support.

<u>New beef progeny test program</u>

The objective of the beef program is to increase genetic gain, by progeny testing some 100 bulls/year (75 daughters per bull) across all of the main beef breeds, with all bulls having full progeny test proofs at the end of 4 years (including maternal proofs). The program would have 3 main elements;

Registrar of elite cows,
Performance & progeny test of high index young bulls,
Return of elite progeny test bulls.

(a) Registrar of elite cows

Each of the main beef breeds would have a 'registrar' of elite females. This registrar would initially comprise only a few cows (i.e., bull-mothers) but would build over time to contain some 300 cows for the larger beef breeds and 100 cows for the smaller beef breeds, resulting in approximately 2,000 elite cows across all breeds. These cows would be selected on the basis of; (i) overall beef EBI, (ii) genetic diversity within their population & (iii) physical conformation. Maintenance of the elite female registrar would be the responsibility of the relevant herd-book, working in consultation with ICBF and the AI industry. From this group of 2,000 elite females, some 300 male calves would be selected each year for performance testing at Tully, with the top 1/3rd within each breed then selected for subsequent progeny testing (i.e., top 100 bulls).

(b) Performance & progeny test of high index young bulls

Bulls would be performance and progeny tested at the central performance test station (Tully). Given the change in emphasis for bull selection (towards total profit as opposed to growth), it is proposed that a review of the Tully regime (i.e., duration of test, diet and traits recorded) be undertaken. On completion of the performance test, the top 100 bulls (from a total of 300 bulls on performance test) would then undergo a period of semen collection (minimum of 1,000 doses/bull), with 600 straws/bull being dispatched to "targeted" beef herds for progeny testing and the remaining being kept in storage for "elite" matings (to cover the scenario where a bull does not return to active AI service, due to health-related problems or injury). It is anticipated that some 1,500 herds will be required for the progeny test program (testing 100 bulls). All herds would receive a minimum of 25 straws (5 bulls x 5 straws), with a view to getting 5 female replacements/herd. The distribution of semen to targeted herds would be co-ordinated centrally by ICBF through AI service providers. Farmers would simply nominate their AI service provider and semen would be dispatched accordingly. To ensure a high level of uptake for the program amongst commercial farmers, there would be a number of incentives attached to the program including;

An incentive of €250 per replacement heifer (having a weaned calf);

An incentive of €100 per male animal slaughtered in Irish abattoirs;

A focused 'herd breeding program' including; (i) access to regional progeny test co-ordinator (who would oversee the program), and (ii) a range of options for participating farmers including access to test bull semen, synchronisation drugs, a technician service & a scanning service.

(c) Return of elite progeny test bulls

From the initial group of 100 progeny tested bulls, it is anticipated that some 20-25 bulls/year would be returned as 'elite progeny test bulls' (across all of the beef breeds). It is critical that semen from these bulls is available for elite matings and that a proportion of these sires are also available to Irish farmers through commercial AI.

Elite matings. The collection of additional semen at Tully (i.e., an extra 400 straws) will ensure that in all circumstances top genetics are available for elite matings.

Commercial AI. For the program to work optimally, a set number of bulls (5-8 bulls/year) need to be returned each year to Irish farmers through commercial AI.

(d) Cost/benefits of the program

Total income from the program (Tully bull charge, breeding female charge & industry support) is expected to €7.16 million (500 bulls progeny tested by 2013). On the negative side, the total cost of the program is expected to be €24.54 million (principally financial incentives for beef farmers), leaving an operating shortfall of some €17.38 million (or 70% of the total cost of the program). When expressed on a per year basis, this equates to approximately €2.5 million over the 7 years of the program (2007-2013), which is considerably less than the expected benefits from the program, some €18 million for Irish beef farmers and the beef industry.

At this stage, the proposition has received widespread support from the beef industry, the main benefits being; an opportunity for the Irish beef industry (farmers, DAF, cattle breeding organisations, meat & milk processors) to substantially increase profit from cattle breeding from the current €1-2 million/annum to €18 million/annum at a relatively low cost.

Conclusion

The benefits of cattle breeding are permanent (they stay with the animal in its lifetime), cumulative (they pass from generation to generation), and are highly cost-effective (i.e., for an investment of €2.5 million in a new progeny testing program, the Irish beef industry could expect to accrue benefits in the region of €18 million). However, to achieve these improvements, cattle-breeding must be structured, systematic and science-based. ICBF have invested much time, resource and effort into establishing systems of beef recording, genetic evaluation and breed improvement that are world leading. The opportunity now exists to tap into these benefits and move beef cattle breeding onto a new level for Irish beef farmers and the beef industry. The simple question is *can we afford to miss the opportunity?*

Relationship between Beef Carcass Classification Grades with Meat Yield and Value

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Introduction

The national cow herd has changed considerably during the last twenty years resulting in a change in the type of carcass produced. Total cow numbers increased from 2.08 million in 1984 to 2.35 million in 2005, with beef cows showing almost a 3 fold increase and dairy cows now at only two-thirds the 1984 level (Table 1). Associated with this change was an increase in the proportion of progeny of continental sire breeds from 17% of the calf crop in 1985 to 56% in 2005. In addition the proportion of continental x dams in the suckler herd has increased from 29% in 1992 to 69% in 2005.

Table 1. Cow numbers (million)

	Dairy	Beef	Total
1984	1.64	0.44	2.08
2005	1.12	1.23	2.35

Source: CSO (1985 and 2005)

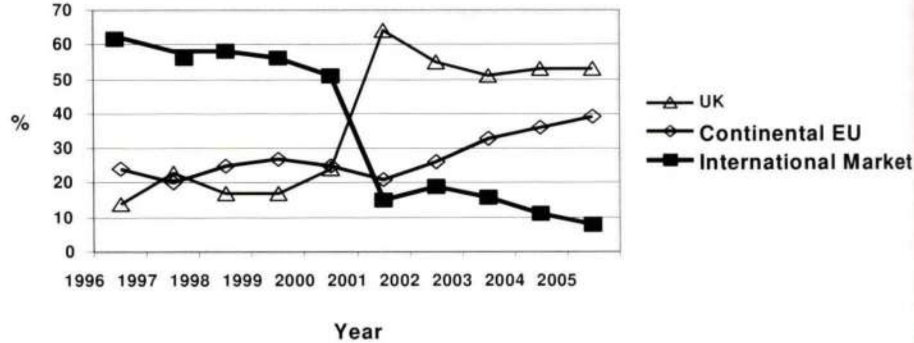
Total cattle disposals are approximately 2 million yearly of which 1.8 million are slaughtered in Ireland. Live exports have varied from 134,000 to 218,000 in recent years (Table 2). Approximately 14% of beef output is destined for the home market, with the remainder exported. The destination of Irish beef exports has changed considerably over the last 10 years. In the years 1996 to 2000 international markets accounted for 51 to 62% of total exports, but in 2001 they declined to 15% and further decreased to only 8% in 2005 (Figure 1). Although the United Kingdom (UK) market showed the greatest increase in Irish beef exports from 2001, exports to continental EU countries have increased gradually in recent years. While the UK market accounted for 53% of total beef exports in 2005 and continental EU markets accounted for 39%, the monetary value of exports was the same for both markets (Table 3).

Table 2. Irish cattle disposals ('000)

	2003	2004	2005
Live exports	218	134	186
Slaughtered	1,860	1,831	1,684

Source: Bord Bia (2006a)

Figure 1. Destination of Irish beef exports as carcass weight equivalent (%)



Source: Bord Bia (2006a)

Table 3. Value of Irish beef exports (excluding offal) 2005

	Million €	%
UK	629	48
Continental EU	622	48
International	47	4
Total	1298	100

Source: Bord Bia (*pers. comm.*)

A breakdown of beef meat exports in 2005 shows that only 15% is exported as bone-in with 72% in boneless form and 14% processed (Table 4). Therefore, with boneless sales predominating, meat yield and distribution (proportion in higher value cuts) are important determinants of carcass value.

Table 4. Breakdown of beef exports %

Bone-in	15
Boneless	72
Processed	14

Source: Bord Bia (*pers. comm.*)

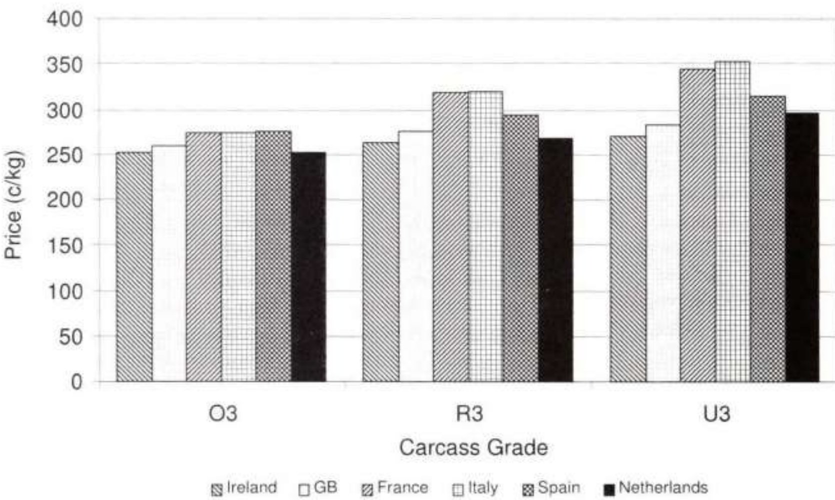
Beef carcasses are graded for conformation (EUROP scale with E best for conformation) and fatness (scale 1 to 5 with 5 fattest) as part of the carcass classification system, which also includes category (steer, heifer, young bull, cow, bull) and carcass weight.

Conformation score has a major effect on carcass price. However, there is considerable variation between EU countries in the price difference between the various conformation classes (Figure 2). The data shows that relative to Irish prices (100) for O3 steers in 2005, the corresponding steer (or bull) relative prices in Great Britain (GB), France and Italy were 103, 108 and 108, respectively. For R3s the corresponding relative prices were 100, 105, 121 and 121 while the prices for U3s were 100, 105, 127 and 137. Similar findings were evident for heifers (Figure 3). Therefore, while the price of O3 carcasses in Ireland and GB were not far below those in continental EU, the difference for R3 and U3 carcasses particularly when compared to France and Italy were substantial. Thus, market outlet is an important determinant of price. Such price advantages have implications for the future viability of suckler beef production in Ireland, which is the principal source of animals with good conformation.

If carcass grades are to be used for price purposes it is important to know how the grades relate to meat yield and distribution in the carcass. The importance of meat distribution is evident from the fact that following fat removal, the cube roll, fillet and striploin only account for 7 to 8% of carcass weight but about 30% of carcass value.

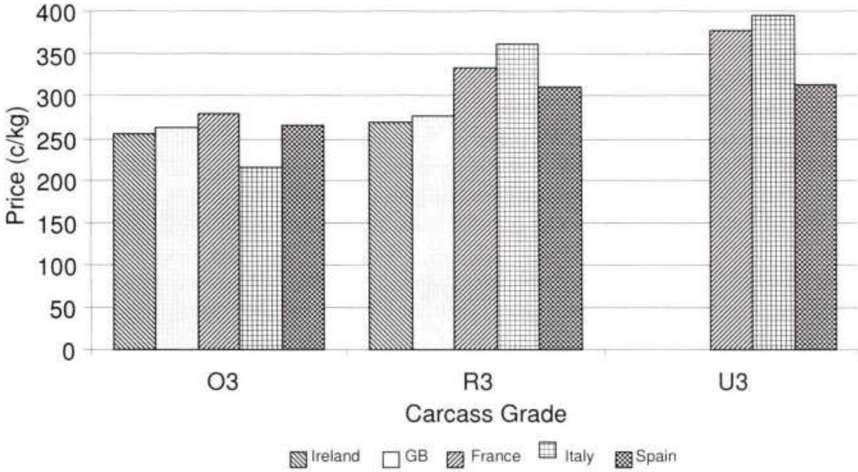
The objectives of the study were to examine the relationship between carcass conformation (CS) and carcass fat (FS) scores with (1) carcass meat, fat and bone proportions, (2) the proportion of high-priced meat cuts in the carcass and (3) carcass value.

Figure 2. Steer (bulls in Italy, Spain and Netherlands) carcass prices for 2005 (c/kg excluding VAT)



Source: Bord Bia (2006b)

Figure 3. Heifer carcass prices for 2005 (c/kg excluding VAT)



Source: Bord Bia (2006b)

Steer Experiment

Materials and Methods

A total of 134 steers were used representing the various sections of the carcass classification grid for conformation and fatness. Carcasses were mechanically graded according to the EU Beef Carcass Classification Scheme. Carcass meat, fat and bone proportions were obtained by dissection of the right side of each carcass, which was split into an 8 rib pistola hindquarter and the remainder as forequarter. The pistola was dissected into 12 meat cuts (silverside, topside, knuckle, rump, tail of rump, fillet, striploin, cube roll, cap of ribs, leg, heel and salmon). The bones were removed and scraped clean. All dissectable fat was removed from each cut. The weight of each cut and total weight of fat trim, lean trim and bone were recorded for the pistola. The forequarter was dissected into 11 cuts (front shin, brisket, chuck, neck, flat ribs (1 to 5), plate, leg of mutton cut, bladesteak, braising muscle, chuck tender and clod) and a similar dissection procedure was undertaken as outlined for the pistola. For both quarters, lean trim was added to the meat cuts to give meat yield. Total carcass yields of meat, fat and bone were the combined values for the pistola and forequarter. Carcass value was taken as twice the sum of the commercial values of the individual meat cuts and meat trim in the half carcass with a deduction for bone. Thus, when estimating carcass value the weight of carcass fat was not taken into consideration.

Results

The slaughter and carcass weight of the steers were 619 and 319 kg, respectively. Regression analysis were used to quantify the relationship between carcass conformation and fat scores with carcass meat, fat and bone proportions, meat distribution and carcass value (Tables 5 and 6). A one unit increase in carcass conformation score (e.g. O3 to R3) increased meat yield by 4.2 percentage units and decreased fat and bone yield by 1.8 and 2.3 percentage units, respectively. A one unit increase in conformation score also increased high-value cuts by 0.6 percentage units and increased carcass value by 22 c/kg.

The effect of a 1 unit increase in carcass fat score was an increase of 3.0 percentage units in fat and decreases of 2.2 and 0.7 percentage units in meat and bone respectively. There was also a reduction of 0.2 percentage units in high priced cuts. A one-unit increase in fat score decreased carcass value by 9 c/kg. Thus, unit changes in conformation score have more than twice the effect on meat yield and carcass value as similar changes in fat score. In addition there is a minimum fat requirement that varies with the actual market (greater in the UK than in continental EU) and thus, unlike conformation, changes in fat score do not apply across the entire classification grid.

Table 5. The effect of a 1 unit increase in conformation score in steers (No = 134)

	O3	R3	Difference
Meat (%)	66.7	70.9	+4.2
Fat (%)	11.8	10.0	-1.8
Bone (%)	21.3	19.0	-2.3
High value cuts (%)	6.9	7.5	+0.6
Value (c/kg carcass)	281	303	+22

Table 6. Effect of a 1 unit increase in fat score in steers (No = 134)

	O3	O4	Difference
Meat (%)	66.7	64.5	-2.2
Fat (%)	11.8	14.8	+3.0
Bone (%)	21.3	20.6	-0.7
High value cuts (%)	6.9	6.7	-0.2
Value (c/kg carcass)	279	270	-9

<u>Suckler v Holstein/Friesian steers</u>

Included in the 134 steers were 20 sucklers which were about ⅞ continental breeds and 65 Holstein/Friesians. The carcass weights of the sucklers and Holstein/Friesians were 376 and 310 kg, respectively (Table 7). Corresponding conformation scores were R^+ and O^- while both had similar fat scores of 3^+. The sucklers had 7.5 (72.3 v 64.8) percentage units more meat, 3.1 (9.9 v 13.0) percentage units less fat, 4.4 (17.8 v 22.2) percentage unit less bone, 1.1 (7.8 v. 6.7) percentage units more high-value cuts and were valued at 44 c/kg more than the Holstein/Friesians.

Table 7. Data for Suckler v. Holstein/Fr steers

	Sucklers	Holstein/Fr
Carcass wt. (kg)	376	310
Carcass grade	R^+ 3^+	0^- 3^+
Meat (%)	72.3	64.8
Fat (%)	9.9	13.0
Bone (%)	17.8	22.2
High value cuts (%)	7.8	6.7
Value (c/kg)	315	271

Young bull and heifer experiments

Carcass dissection studies, using procedures similar to those outlined for steers were carried out using 74 young bulls (52 sucklers and 22 Holstein/Friesians) slaughtered at 14 to 16 months of age, and 40 heifers (36 suckler and 4 Continental X Holstein/Friesians) slaughtered at 20 months of age. The effect of carcass conformation score (and fat score) on carcass composition and carcass value was similar to that outlined for the steers. The effect of a one unit increase in carcass conformation score in the bulls on yield (percentage units) was +3.6, -1.3, -2.3 and +0.3 for meat, fat, bone and high-value cuts, respectively (Table 8). The corresponding figure for the heifers was +4.5, -2.1, -2.3 and +0.6 (Table 9). The effect of a unit increase in conformation score on carcass value was +18 c/kg for the bulls and +25 c/kg for the heifers.

Table 8. Effect of a 1 unit increase in conformation score in bulls (No=74)

	O3	R3	Difference
Meat (%)	65.7	69.2	+3.6
Fat (%)	11.6	10.3	-1.3
Bone (%)	22.8	20.5	-2.3
High value cuts (%)	6.7	7.0	+0.3
Value (c/kg carcass)	278	296	+18

Table 9. Effect of a 1 unit increase in conformation score in heifers (No = 40)

	O3	R3	Difference
Meat (%)	66.7	71.2	+4.5
Fat (%)	12.3	10.2	-2.1
Bone (%)	21.1	18.8	-2.3
High value cuts (%)	7.4	8.0	+0.6
Value (c/kg carcass)	292	317	+25

Comparison of meat yield and distribution results with market prices

The price advantage between U3 and O3 steer or bull carcasses in 2005 varied from 17 c/kg in Ireland to 70 to 80 c/kg in France and Italy (Table 10). With the exception of Ireland and GB the advantage in EU countries was equal to or considerably greater than the 44 c/kg calculated for steers and 36 c/kg for bulls in the present study based on meat yield and distribution. While there are no Irish or GB quotations for heifers grading U for conformation, it is noticeable that in continental EU markets the effect of conformation on heifer prices is even greater than for steers/bulls. It is evident that the cattle pricing structure in Ireland must be reviewed if emphasis in breeding goals are to be placed on improving carcass meat yield and distribution in addition to meeting export market requirements.

Table 10. Price difference (c/kg) between carcasses grading R3 or U3 over O3 in 2005

	Present study	Ireland	GB	France	Italy	Spain
Steer (bull)						
R3 v. O3	+22	+10	+16	+44	(+35)	(+17)
U3 v. O3	+44	+17	+23	+70	(+79)	(+39)
Heifer						
R3 v. O3	+25	+13	+15	+54	+145	+45
U3 v. O3	+50	-	-	+98	+187	+49

Beef carcass classification

Beef carcass classification data for 2005 shows that 87% of steers and 91% of heifers fall into the combined conformation classes of O and R (Table 11). Therefore, a better differentiation would be achieved by grading on a 15 point scale (eg R$^-$, R, R$^+$) rather than on a 5 point scale. For the same reason it would be more informative to have carcass fat class also graded on a 15 point scale (Table 12). The mechanical grading system currently in operation at Irish Meat processing plants would facilitate this expanded grading system.

Table 11. Percentage of beef carcasses in the different conformation classes in 2005

	E	U	R	O	P	Carcass wt (kg)
Steers	-	6	46	41	7	352
Heifers	-	6	57	34	3	286
Cows	-	1	11	47	40	304

Source: DAF (2006)

Table 12. Percentage of beef carcass in the different fat classes in 2005

	1	2	3	4L	4	4H	5
Steers	1	10	52	20	11	5	1
Heifers	2	9	41	21	14	9	4
Cows	9	11	30	16	12	10	10

Source: DAF (2006)

It is suggested that using this expanded beef carcass classification system for conformation and fatness and a pricing system as outlined in Table 13 would be of benefit to the Irish beef industry.

Table 13. Suggested price differences for carcass classification grades

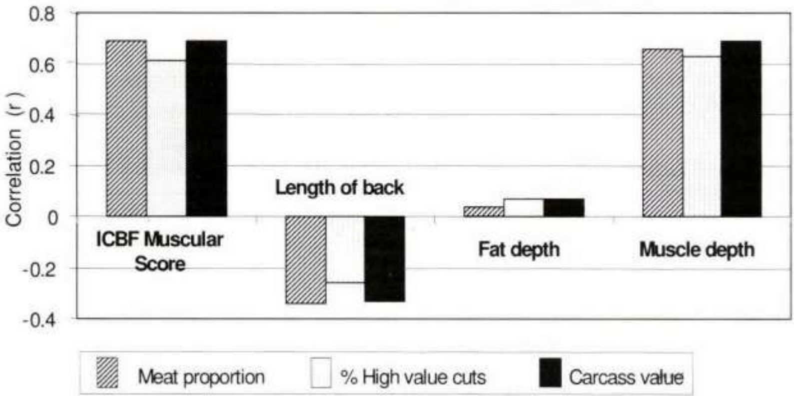
	Carcass conformation score									
	P+	O-	O	O+	R-	R	R+	U-	U	U+
c/kg carcass	-18	-12	-6	0	+6	+12	+18	+24	+30	+36

	Carcass fat score								
	3-	3	3+	4-	4	4+	5-	5	5+
c/kg carcass	0	0	0	-2.5	-5.0	-7.5	-10.0	-12.5	-15.0

Live Animal Assessment

Discussion to date has shown effects of carcass conformation and fat scores on meat yield, percent high value cuts and carcass value but in cattle improvement programmes it is also necessary to be able to use evaluations on the live animal. High correlations were obtained between visual muscular scores and ultrasonically scanned muscle depth at the third lumbar vertebra with meat yield, the proportion of high value cuts and carcass value (Figure 4). Although live animal skeletal scores or scanned fat measurements were not useful, the data shows that live animal scores/measurements are useful in beef improvement programmes.

Figure 4. Correlation of muscular scores and length of back visually assessed and scanned fat and muscle depth with meat proportion, % high-value cuts and carcass value



Recommendations

Carcass grading for conformation and fatness should be on a 15-point scale.

A price premium per unit improvement in conformation of at least 6 c/kg on a 15- point scale (= 18 c/kg on a 5-point scale) is merited based on the results of the present study.

A deduction in carcass price per unit increase in fat score of 2.5 c/kg on a 15-point scale (=7.5 c/kg on a 5-point scale) above a fat score of 9 on a 15-point scale (3⁺ on a 5-point scale).

Implications of Using the Suggested System

Use of such a system would be of major benefit to the beef industry by providing a clear message for producers on carcass value and market requirements. This would result in:

An overall improvement in the quality of beef produced.

Improved financial viability of suckler units which are the source of the higher quality beef carcasses.

More animals suitable for the high-priced continental EU markets.

The provision of clear guidelines to those involved in cattle genetic improvement programmes such as ICBF, AI organisations and Breed Societies.

The provision of a fairer system for payment, which ensures that payment is based on carcass value.

Conclusions

Increased CS increased carcass meat yield, the proportion of high-priced cuts in the carcass and carcass value while decreasing carcass fat and bone proportions.
Increasing FS increased carcass fat proportion and led to a decrease in the proportions of carcass meat, bone and high-value cuts and carcass value.
Muscular scores and scanned muscle depth were shown to be good predictors of the proportion of carcass meat, bone and high value cuts and carcass value but were poor predictors for carcass fat proportion.
Skeletal scores showed a poor negative relationship with carcass meat yield and value.
Recommend that: Grade carcasses on a 15-point scale e.g. conformation R-, R, R+.
: Conformation premium of at least 6c/kg on 15 point scale (=18 c/kg on 5 point scale).
: Monetary deductions for over-fatness.

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Alternative Forages to Grass for Ensilage and as Feeds for Beef Cattle

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This paper will deal with:
Ensiling and feeding alternative forages to grass
Conserving and feeding high-moisture grain
Alternative forages to grass for grazing

Ensiling and feeding alternative forages to grass
Grass is the predominant forage ensiled in Ireland, and is likely to remain so for the foreseeable future. If as is predicted, cereal prices continue to increase in the years to come, recent downward trends in the attractiveness of conserved grass relative to concentrate feedstuffs are likely to be reversed. It is important to remember that besides providing winter feed, grass silage also facilitates grazing management, permits efficient and hygienic recycling of animal manures and can be used to help reduce the internal parasite challenge to grazing cattle. High yields of quality grass ensiled with minimal losses and produced/conserved/fed with restrained input costs will therefore continue to be essential in order to provide cattle with an economically attractive feedstuff and to support sustainable systems on most farms.

However, the relatively modest yields achieved in a single harvest, allied to variability in digestibility and ensilability (and thus intake and animal performance response), and the likelihood of effluent production can create disadvantages for grass silage compared to some alternative forage crops. Thus, alternative forages are worthy of consideration. However, it is important to remember that the function of any of these alternatives to grass silage is to improve farm profits and not simply to increase intake or levels of animal production. Consequently, the role for alternative forages needs to be considered in terms of factors such as relative total costs of production, relative revenues from the sale of meat, relative payments of eligible EU funds and ultimately farm profits.

Crops for which summaries of Irish research results will be presented in this paper include forage maize, whole-crop cereal silage (wheat, barley and triticale), whole-crop fodder beet silage and red clover.

<u>Maize silage</u>
High dry matter (DM) yields are necessary in order to provide feedstuff, and ultimately meat, at a competitive cost. A target of 13t DM/ha harvested whole-crop forage maize in the absence of plastic mulch (15.5 tDM/ha, or higher, where plastic mulch is used) is appropriate for crops to compete economically with good grass silage.

Excellent quality is essential if there is to be a consistent economic benefit over good grass silage. Any potential superiority in the nutritive quality of maize silage is driven mainly by its content of starch, and thus of grain. Good quality crops will have half of their harvested

DM contributed by well-filled cobs (i.e. grain + rachis) with the remainder coming from the stover. Thus, target harvested whole-crop DM concentration should be 30% DM with a corresponding starch concentration above 25% of the DM. The cobs themselves should have reached 50% DM. Since the stover accounts for half of the harvested DM, its quality is also important. The data in Figure 1 show a major decline in stover digestibility (DMD) as the crop matures. Consequently, it is important to balance achieving optimal yield and cob development without over-delaying harvesting to the point where stover digestibility has declined excessively.

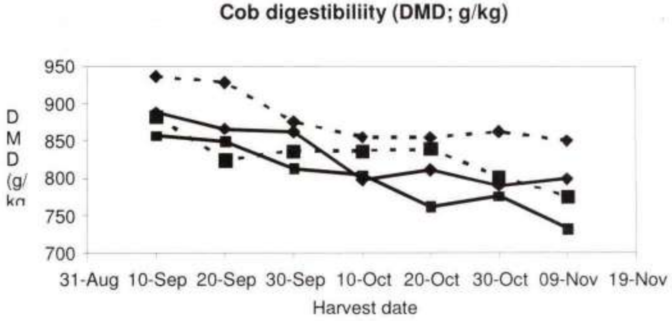
Conservation losses include physical and respiration (i.e. 'heating') wastage during silo filling, losses via effluent or fermentation during ensilage, and respiration or physical wastage again at feedout. The target with maize silage is to restrict these losses to about 12% of the harvested DM.

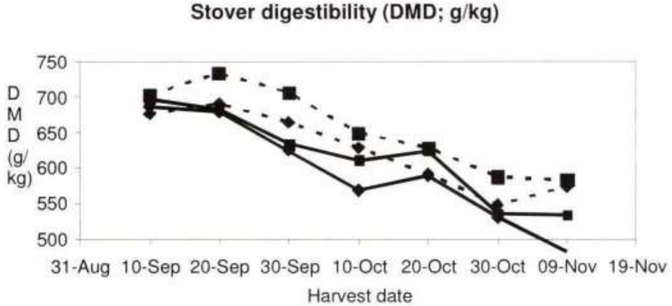
The ensiled forage needs to be immediately and perfectly sealed using two sheets of 0.125mm black polythene sheeting, a complete covering of tyres and the edges well weighted down with silt, sandbags, etc. Rapid sealing of ensiled maize is one important component of the management practices that can help reduce the risk of aerobic deterioration (i.e. heating) at feedout.

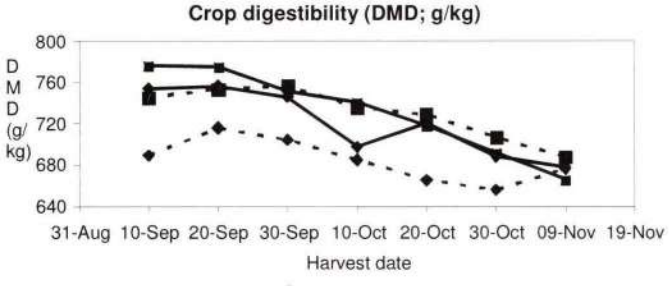
All silages are inherently unstable when exposed to air at feedout, and a considerable range in stability occurs within silages made from any particular crop species. However, across a series of experiments at Grange, maize silage was in general more prone to aerobic deterioration than grass or whole-crop cereal silages. Thus, the operator must demonstrate excellent management of the maize silage face during feedout and subsequently of the silage in the feed trough. The emphasis must be on successfully minimising the duration of exposure of silage to air. In most cases good management practices will be adequate to limit the scale of aerobic deterioration, although in some cases specific additives may be of assistance.

Experiments with maize silage have shown its nutritive value for beef cattle range from being inferior to good grass silage (Table 1), to being superior (Table 2). Thus, highly digestible maize silage of high grain (i.e. starch) content can support rates of carcass gain by beef cattle that are superior to what are achieved with good grass silage, but with a somewhat lower efficiency of converting ingested forage DM to carcass. Similarly, diets based on *ad libitum* access to maize silage supplemented with 3kg concentrates daily supported live- and carcass-weight gains by cattle of 84 – 86% and 83 – 91%, respectively, of diets based on *ad libitum* concentrates (+ 1kg forage DM daily), and with total DM intakes at 94 – 97% of the high-concentrate diet (Tables 6 and 7).

Figure 1. Patterns of change in yield, plant components and plant constituents as forage maize matures during autumn 2002 (Little *et al.*, 2005a,c)







There was a slight trend towards a higher carcass gain by cattle offered a mixture of grass and maize silages compared to the calculated estimate based on their performance when offered either silage alone. However, the data in Tables 1 and 2 do not indicate that a significant synergistic benefit is necessarily obtained by cattle offered a mixture of grass + maize silages relative to the average of animals offered grass silage or maize silage alone.

Table 1. Intake, performance and feed conversion efficiency for maize silage (low starch content)

	% grass silage in mix with maize			
	100	67	33	0
Silage DM intake (kg/day)	6.1	7.2	7.1	6.1
Liveweight gain (g/day)	1385	1384	1371	1068
Carcass weight gain (g/day)	870	829	745	633
Kill-out rate (g/kg liveweight)	526	520	509	515
Kidney & channel fat weight (kg)	12.2	10.8	10.7	9.7
Feed conversion efficiency (FCE)				
Dietary DM intake/livewt. gain	6.3	7.0	7.0	8.1
Dietary DM intake/carcass gain	10.0	11.8	12.8	13.5

(Well preserved unwilted grass silage of DMD = 74.6%; Hf. X Fr. steers with starting liveweight of 481kg offered 3kg concentrates per head daily for 87 days) (O'Kiely and Moloney, 1995b)

Table 2. Intake, performance and feed conversion efficiency for maize silage (high starch content)

	% grass silage in mix with maize		
	100	50	0
Silage DM intake (kg/day)	5.1	6.8	6.8
Liveweight gain (g/day)	846	950	979
Carcass weight gain (g/day)	653	698	737
Kill-out rate (g/kg liveweight)	552	548	554
Kidney & channel fat weight (kg)	13.8	12.8	12.2
Feed conversion efficiency (FCE)			
Dietary DM intake/livewt. gain	9.4	10.2	9.9
Dietary DM intake/carcass gain	12.0	13.6	13.0

(Well preserved unwilted grass silage of DMD = 74.4%; Char. X heifers with starting liveweight of 443kg offered 3kg concentrates per head daily for 170 days) (O'Kiely and Moloney, 2000b).

Research at Grange indicates that, relative to grass silage, maize silage produced a whiter carcass fat but a similar colour for lean tissue when both silage types were compared under similar conditions. Both silages had similar direct effects on meat toughness when compared at similar carcass weight (Keady, 2005; Little *et al*., 2005a,b,c; Moloney *et al*., 1999,2000; Muck and O'Kiely, 1992; O'Kiely, 1998; O'Kiely and Moloney, 1995b,2000a; O'Kiely *et al*., 1998; O'Kiely and Muck, 1992; Walsh *et al*., 2005a,b; Walsh *et al*., 2006).

Whole-crop cereal silage

Issues relating to target yield, quality and conservation losses for whole-crop cereal (small grain cereals – wheat/barley/triticale) are similar to those for maize silage. Target yields should be those relevant to commercial grain production (e.g. 10t winter wheat grain or 7t spring barley grain per ha) with target qualities depending on half of the harvested crop DM being in the grain. The digestibility of the remaining half of the crop (straw + chaff) will clearly influence quality (i.e. feed value).

Experiments with whole-crop cereal silage conserved using conventional technologies indicate that:

- Whole-crop cereal silage is made from autumn or spring sown crops such as wheat, barley, oats or triticale (a hybrid of wheat and rye), and is harvested at a more mature growth stage than arable silage. Unlike arable silage, it is not usually undersown with grass. It is grown as for high yielding commercial grain production using best tillage practices, and has conventionally been harvested at DM concentrations between 35 and 60%. In different countries, different practices have developed for how to ensile such crops, and new technologies for conserving these crops are still being developed. The relatively high DM concentration ensures that there will be no effluent and that preservation should be straightforward. The same requirements for rapid filling and perfect sealing of silos hold as described for forage maize. Additionally, whole-crop cereal silage needs to be protected from wildlife such as birds, rodents, etc. – this can sometimes be quite a challenge.

- Harvesting should not take place until after the cereal grain has progressed beyond the milky-ripe growth stage – until it has at least reached the soft-cheddar consistency (i.e. above 35% DM) (Table 3).

- Crop nutritive value is effectively constant from the 'soft-cheddar' stage until the cereal grain has reached the hard-cheddar consistency (approx. 55% DM) – this is a window of almost three weeks (Tables 4 and 5).

- No consistent benefit (and sometimes disadvantages) accrues from treating the crop with urea (i.e. using conventional technologies). The attractions of urea are that it increases crop crude protein content, restricts mould growth at feedout and has the potential to upgrade fibrous feed (alkali effect). If used, it should be applied only to crops above 50% DM. If urea is applied to crops of 40% DM, intake and animal performance may well be reduced (possibly severely) (Tables 3 and 4).

Table 3. Whole-crop barley (WCB) or wheat (WCW) silage offered to beef cattle supplemented with concentrates

	Dry matter content (%)	Silage DM intake (kg/day)	Liveweight gain (g/day)	Carcass gain (g/day)
Experiment 1 (WCB)				
Grain milky ripe	26	-	617	292
Grain mealy ripe	35	-	869	442
Experiment 2 (WCB)				
No additive	34	6.6	1166	629
Urea	36	5.8	1140	634
Experiment 3 (WCB)				
No additive	46	6.8	712	374
Urea	48	7.9	783	477
Experiment 4 (WCW)				
No additive	43	3.8	645	-
Urea – low rate	39	3.2	509	-
Urea – high rate	45	2.6	362	-
Grass silage	22	3.7	719	-

(Exp. 1: Fr. steers with starting liveweight of 502kg offered 1.75kg concentrate/hd/d for 95 days; Exp. 2: Hf. X heifers with starting liveweight of 323kg offered 2.9kg concentrate/hd/d for 101 days; Exp. 3: Hf. X heifers with starting liveweight of 347kg offered 1kg concentrate/hd/d for 84 days; Exp. 4: Char. X heifers with starting liveweight of 230kg offered 2kg concentrate/hd/d for 112 days; Exp. 4: Well preserved unwilted grass silage of DMD = 74.2%; Hf x Fr steers with starting liveweight of 433kg offered 3kg concentrate/hd/d for 170 days) (O'Kiely and Moloney, 1995a).

Table 4. Intake, performance and feed conversion efficiency for whole-crop wheat (modest grain yield)

	Whole-crop wheat silage			Grass silage
Crop DM% at harvest	35% DM	50% DM		
Additive applied	Alone	Alone	Urea	
Silage DM intake (kg/day)	5.14	5.76	5.45	4.98
Liveweight gain (g/day)	889	921	894	1051
Carcass gain (g/day)	575	577	529	747
Kill-out rate (g/kg liveweight)	529	524	515	552
Kidney & channel fat weight (kg)	10.0	9.5	10.3	11.1
Feed conversion efficiency (FCE)				
Dietary DM intake/livewt. gain	9.0	9.2	9.3	7.3
Dietary DM intake/carcass gain	13.7	14.8	15.8	10.2

(Well preserved unwilted grass silage of DMD = 75.2%; Char X heifers with starting liveweight of 440kg offered 3kg concentrate/hd/d for 161 days) (O'Kiely and Moloney, 1999b).

Table 5. Intake, performance and feed conversion efficiency for whole-crop wheat (good grain yield)

	% grass silage (GS)	% GS with whole-crop wheat ensiled at 36%DM			% GS with whole crop wheat ensiled at 51% DM plus urea		
	100	67	33	0	67	33	0
Intake (kg silage DM/day)	4.81	5.35	6.27	6.33	6.26	6.01	5.96
Liveweight gain (g/day)	866	941	1019	987	1031	968	869
Carcass gain (g/day)	596	684	706	695	710	711	636
Kill-out rate (g/kg liveweight)	534	539	534	534	533	542	537
Kidney & channel fat weight (kg)	11.4	9.4	10.7	9.3	8.5	9.0	10.5
Feed conversion efficiency (FCE)							
Dietary DM intake/carcass gain	12.6	11.7	12.8	13.1	12.5	12.4	13.7

Well preserved unwilted grass silage of DMD = 73.2%; Cont. X heifers with starting liveweight of 426kg offered 3kg concentrates per head daily for 142 days (O'Kiely and Moloney, 2002).

- The nutritive value of whole-crop cereal silage for beef cattle can range from being inferior to good grass silage (Table 4) to being superior (Table 5), with the difference in nutritive value relativity being predominantly determined by the content of developed grain. The digestibility of the straw component of the crop is also important. However, the proportion of grain in the crop will have a major bearing on whole-crop nutritive value, and higher grain yields and/or lower yields of harvested straw can influence this. Excellent whole-crop cereal can have nutritive value very similar to maize silage, but probably with a somewhat inferior feed conversion efficiency (Tables 6 and 7). Furthermore, winter wheat and spring barley, both at approximately 50% grain in the harvested DM, can have a similar (and excellent) nutritive value (Table 7).

Table 6. Feed DM intake, growth, kill-out proportion and feed conversion efficiency (FCE) for grass, maize and whole-crop wheat (WCW) based diets

	Grass silage	Maize silage	Fermented WCW	Alkalage WCW	*Ad lib.* Concs.
Forage DM intake (kg/d)	4.54	6.75	7.07	7.56	0.95
Total DM intake (kg/d)	7.07	9.27	9.59	10.06	9.86
Liveweight gain (g/d)	802	1200	1149	1132	1302
Carcass gain (g/d)	479	776	723	686	851
Carcass weight (kg)	290	335	329	321	348
Kill-out (g/kg)	523	547	539	532	551
FCE (kg DM intake/kg carcass gain)	15.2	12.1	13.5	14.8	11.9

Unwilted grass silage of DMD = 67.4%; Cont. X steers with starting liveweight of 424kg offered 3kg concentrates per head daily for 160 days (Walsh *et al.*, 2005a).

Table 7. Feed DM intake, growth, kill-out (KO) proportion, carcass and fat scores and feed conversion efficiency (FCE) for maize and whole-crop cereal silages

	Maize silage	Fermented WCW	Fermented HCW	Fermented WCB	Fermented HCB	*Ad lib.* Concs.
Forage DM intake (kg/d)	6.58	7.22	7.08	7.21	6.82	1.29
Total DM intake (kg/d)	9.21	9.84	9.71	9.84	9.44	9.51
Liveweight gain (g/d)	1235	1254	1237	1151	1208	1473
Carcass gain (g/d)[1]	781	741	758	736	780	939
Carcass weight (kg)	344	338	341	337	344	366
Kill out (g/kg)	541	529	535	541	545	549
Kidney & channel fat (kg)	9.03	9.53	10.21	8.55	9.32	9.26
Conformation score[2]	3.27	2.80	3.00	3.00	2.93	3.30
Fat score[3]	3.14	3.31	3.19	3.11	3.41	3.55
FCE[4]	12.0	13.5	13.1	13.6	12.4	10.3

[1] Assuming an initial KO rate of 50%; [2] Based on E=5, U=4, R=3, O=2, P=1; [3] Based on 1=1, 2=2, 3=3, 4L=3.7, 4H=4.3, 5=5; [4] Feed conversion efficiency expressed as kg DM intake/kg carcass gain; WCW = whole-crop wheat; HCW = head-cut wheat; WCB = whole-crop barley; HCB = head-cut barley; Cont. X steers with starting liveweight of 438kg offered 3kg concentrates per head daily for 160 days (Walsh *et al.*, 2006).

- It can be speculated that allowing the crop ripen so that crop DM concentrations increase beyond 60% DM would allow grain nutritive value to increase. However, this would produce grain that if not processed, would be more likely to pass through the animal undigested (thereby significantly reducing effective nutritive value). Furthermore, the straw component of this more mature crop can be expected to have diminished digestibility (further decreasing nutritive value). Such a crop should benefit from its grain being processed, with an accompanying urea/urease treatment increasing the overall concentration of crude protein, inhibiting potential mould activity and possibly contributing to upgrading the fibre fraction of the harvested crop. The comparison of 'Fermented WCW' and 'Alkalage WCW' shown in Table 6 involved the same crop of winter wheat being cut to the same stubble height when the crop was at 40% DM and again three weeks later when at 71% DM. The later harvested grain was processed at harvesting and the crop treated with a urea-based additive. The results in Table 6 show a relatively similar nutritive value for the 'Fermented WCW' and the 'Alkalage WCW' when offered to finishing beef steers.

- Raising the cutting height of a crop (i.e. higher stubble) should shift the balance between grain and straw+chaff towards grain, thereby increasing silage nutritive value. However, in an experiment (Table 7) where the cutting height of winter wheat (67cm plant height) was 12 (WCW) or 29 (HCW) cm and of spring barley (71 cm plant height) was 13 (WCB) or 30 (HCB) cm, there was no significant impact on animal productivity of elevating cutting height – presumably in these cases cutting height needed to be elevated further before a significant response could be measured.

- Similarly, diets based on *ad libitum* access to fermented whole-crop cereal silage supplemented with 3kg concentrates daily, supported live- and carcass-weight gains by cattle of 82 - 88% and 79 - 81%, respectively, of diets based on *ad libitum* concentrates (+ 1kg forage DM daily), and with total DM intakes at 97 - 103% of the high-concentrate diet (Tables 6 and 7).

- Whole-crop wheat or barley silages should ideally be produced from crops that are between 40 - 45% DM. The target is to have approximately 50% grain in a crop that has 12cm stubble, giving starch content in excess of 20% of the crop DM. Conservation losses should be limited to a target of 12% of harvested DM, producing aerobically stable silage with negligible mould presence.

- The data in Table 5 suggest that a synergistic benefit can be obtained by cattle offered a mixture of grass + whole-crop cereal silages relative to the average of animals offered grass silage or whole-crop cereal silage alone.

- Research by Moloney at Grange indicated that, relative to grass or maize silages, whole-crop (small grain) cereal silage produced a whiter carcass fat but a similar colour for lean tissue when all silage types were compared under similar conditions. Each silage had similar direct effects on meat toughness when compared at similar carcass weight (Keady, 2005; Moloney and O'Kiely, 1994,1997; O'Kiely and Moloney, 1991,1995a,1999b,2000b,2002; Walsh *et al.*, 2005a,b; Walsh *et al.*, 2006).

<u>Whole-crop fodder beet silage</u>

Fodder beet roots and leaves have a high nutritive value, and data have previously been published on the nutritive value of each of these. Both leaves and roots can be ensiled together to produce silage of high nutritive value (Table 8). A whole-crop fodder beet silage based diet can support carcass gains that are 89% that of animals on *ad libitum* concentrates (albeit with an 18% poorer feed DM conversion efficiency). Whole-crop fodder beet can produce large volumes of relatively high quality (i.e. energy) effluent when ensiled, but this can be largely retained within the silo by using sufficient absorbent. Thus, when dry beet pulp nuts were ensiled with whole-crop fodder beet at 159kg/tonne, effluent output declined from 419 to 122l/tonne while carcass gain was not altered (Table 9). (Moloney and O'Kiely, 1999; O'Kiely and Moloney 1999a; O'Kiely *et al.*, 1993).

Table 8. Feed DM intake, growth, kill-out (KO) proportion, carcass and fat scores and feed conversion efficiency (FCE) for grass and whole-crop fodder beet silages

	Grass silage	WCFB silage	*Ad lib.* concentrates
WCFB silage DM intake (kg/d)	0	8.5	0
Grass silage DM intake (kg/day)	5.6	1.2	1.3
Concentrate DM intake (kg/day)	3.5	0.9	8.8
Total DM intake (kg/d)	9.1	10.6	10.1
Liveweight gain (g/d)	906	1084	1255
Carcass gain (g/d)[1]	694	773	870
Carcass weight (kg)	306	316	326
Kill out (g/kg)	536	533	534
Kidney & channel fat (kg)	14.3	14.1	13.8
Conformation score[2]	2.4	2.4	2.7
Fat score[3]	3.3	3.3	3.7
FCE[4]	13.1	13.7	11.6

[1] Assuming an initial KO rate of 48.5%; [2] Based on E=5, U=4, R=3, O=2, P=1; [3] Based on 1=1, 2=2, 3=3, 4L=3.7, 4H=4.3, 5=5; [4] Feed conversion efficiency expressed as kg DM intake/kg carcass gain; WCFB = whole-crop fodder beet; Fr. steers with starting liveweight of 469kg for a duration of 118 days (O'Kiely and Moloney, 1999a).

Table 9. Feed DM intake, growth, kill-out (KO) proportion, carcass and fat scores and feed conversion efficiency (FCE) for whole-crop fodder beet silage

	Untreated WCFB silage	Absorbent-treated WCFB silage		*Ad lib.* concentrates
		Unsupplemented	3 kg meals	
WCFB silage DM intake (kg/d)	6.20	9.22	6.70	0
Grass silage DM intake (kg/day)	1.18	1.18	1.18	1.24
Concentrate DM intake (kg/day)	2.62	0	2.62	9.54
Total DM intake (kg/d)	10.0	10.4	10.5	10.8
Liveweight gain (g/d)	1062	1219	1286	1327
Carcass gain (g/d)[1]	818	830	916	983
Carcass weight (kg)	375	374	384	390
Kill-out (g/kg)	569	557	565	571
Kidney & channel fat (kg)	15.9	16.2	17.4	15.4
FCE[2]	12.2	12.5	11.1	11.0

[1] Assuming an initial KO rate of 53%; [2] Feed conversion efficiency expressed as kg DM intake/kg carcass gain; WCFB = whole-crop fodder beet; Fr. steers with starting liveweight of 554kg for a duration of 99 days (O'Kiely *et al.*, 1993).

Red clover

Red clover is considered a short-lived perennial herbage legume that can be highly productive for two to three years, and whose upright growth habit makes it particularly suited for hay and silage making. Since permanent grassland dominates most ruminant systems in Ireland, the important target for red clover is to greatly improve its persistence and thus its potential contribution to feed supply. An ongoing experiment is quantifying the impacts of cultivar, companion grass, harvest schedule and nitrogen (N) fertiliser on crop yield and digestibility over several years.

Two cultivars (Merviot and Ruttinova) were sown in monoculture (15kg seed/ha) or in a binary mixture with perennial ryegrass (*cv.* Greengold) (10kg red clover + 10kg perennial ryegrass seed/ha) in August 2001. They received 0 or 50kg inorganic N fertiliser/ha each March and had a first-cut harvest date of late May or mid-June. Sequential harvests followed each first cut, with a total of four harvests per system completed by early December. Simultaneously, monoculture plots of perennial ryegrass (*cv.* Greengold; 30kg seed/ha) received 0, 50, 100 or 150kg inorganic N/ha in mid-March and immediately after the first three harvests, with similar harvest dates to the red clover.

Towards the end of the fifth season since reseeding, red clover still dominates some treatments while in others it has long disappeared. Factors favouring the persistence of red clover include no application of inorganic N in March and a first-cut harvest date in late May rather than mid-June. Furthermore, the binary mixture with grass resulted in an improved annual yield and digestibility compared to sowing red clover as a monoculture. In the first year after reseeding, the red clover + grass swards that received no inorganic N fertiliser and had a first-cut harvest date in late May, had an annual DM yield (13.2 t/ha) that was 136 and 86% of perennial ryegrass monocultures that received an annual input of inorganic N fertiliser of 0 and 360kg N/ha, respectively. The corresponding values in the third year (16.4 tonnes DM/ha) were 167 and 95% (O'Kiely *et al.*, 2006).

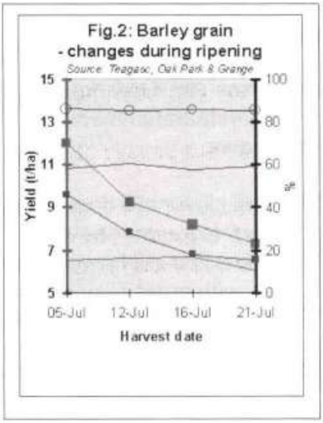
Conserving and feeding high-moisture grain

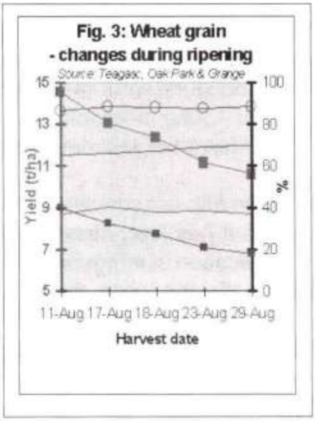
Cereal grains of less than 14% moisture can be safely stored for an extended duration. As grain moisture content rises the duration of safe storage becomes shorter and the requirement for aeration initially and then for drying or other preservation treatment progressively increases. Alternative technologies used in recent years facilitate systems of successfully conserving grain harvested at up to greater than 40% moisture.

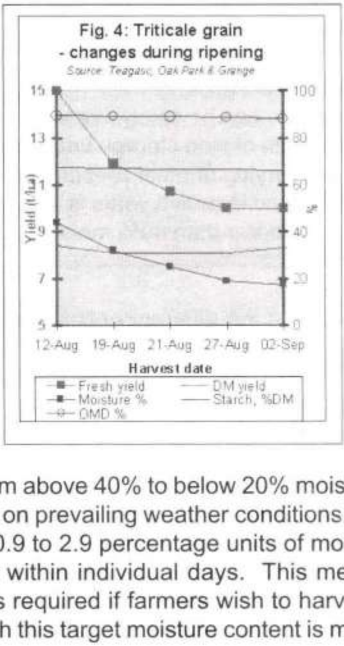
Balance of yield & quality

One important issue when considering the different options for conserving grain is how does the stage of ripening at harvest influence grain yield and quality. During two seasons, crops of winter wheat, barley and triticale were grown and harvested at a series of stages from above 40% to under 20% moisture. The results are summarised in Figures 2 - 4. For each cereal, the fresh yield of grain declined with advancing ripening, reflecting the disappearance of water from the mature grain as it dried. However, if the grain yield at each stage of ripening is expressed with its water content excluded, then the resultant yield of grain dry matter (DM) was constant. Physiological maturity is the point at which grains reach their maximum dry weight, so clearly each of the crops summarised in Figures 2 - 4 had reached physiological maturity prior to the commencement of the study. Consequently, it is important to recognise that the yield of fresh grain is not a helpful indicator of the amount of feedstuff produced, whereas the yield of harvested grain DM is very important.

Figures 2 – 4. Changes in grain yield and quality as cereals ripen (Stacey *et al.*, 2002, 2003)







The ripening process from above 40% to below 20% moisture took from 10 to 22 days, depending on the crop and on prevailing weather conditions. Thus, daily drying rates ranged between a decrease of 0.9 to 2.9 percentage units of moisture per day. In addition, grain drying rates also varied within individual days. This means that frequent monitoring of grain moisture content is required if farmers wish to harvest at a target moisture content, and the duration for which this target moisture content is maintained can be relatively short.

In general, measurements of grain nutritive value such as digestibility (organic matter digestibility - OMD), starch, protein and ash were relatively constant during the ripening process from above 40% to below 20% moisture. The values for OMD and starch can be seen in Figs. 2 - 4. Measurements of ensilability, including sugar content and buffering capacity, indicated that the various moist grains investigated were likely to preserve satisfactorily were they to be ensiled (e.g. crimped grain).

Only in the case of barley when it reached 14-17% moisture was there any apparent loss of grain prior to harvesting. Once the settings on the combine harvester and its forward speed are set appropriately, grain losses during harvesting of each of the cereals should be similar to the values achieved when harvesting conventionally dry grain. Thus;

- Under the prevailing conditions, wheat, barley and triticale probably reached physiological maturity when their grains are somewhere around 40-50% moisture content.
- Beyond this point DM yields and grain nutritive value are usually constant, at least until the ripening grain become very dry.
- There is a 1-3 week time interval between around 40% and 20% moisture, during which farmers can select from among alternative grain conservation strategies in the knowledge that grain DM yield and quality are not changing.
- However, since the rate of drying can vary both across days and within days, frequent monitoring and timely harvesting are required if crops are to be harvested at a target moisture content. This can have implications for the grain conservation strategy chosen, as individual conservation systems have preferred moisture contents at which they are operated

Finishing beef cattle

Farmers thinking of using alternative techniques for preserving and processing cereal grains destined for feeding to beef cattle need to know how the feeding value of such grains compare with grains conserved using more conventional techniques. To answer this question, finishing continental crossbred steers were offered a low digestibility grass silage alone or with wheat-based concentrates at the equivalent (standardised for moisture content) of 3 (low) or 6 (high) kg/head/day, or *ad libitum*, for 144 days. Wheat had been either:

harvested at 30% moisture, crimped (i.e. rolled), treated with a mixture of organic acids and ensiled ('Crimped & ensiled').

harvested at 26% moisture, treated with urea solution and stored under plastic sheeting. This was offered whole (i.e. unrolled) ('Urea-whole').

harvested at 16% moisture, treated with propionic acid and rolled before feeding. This was considered the 'Conventional' or reference treatment.

The 'Crimped & ensiled', 'Urea-whole' and 'Conventional' wheat had pH values 4.3, 9.3 and 4.8, respectively, and corresponding crude protein values of 11.6, 14.5 and 11.1% of the DM.

The results are summarised in Table 10.

Table 10. Feed intake, growth rate and faecal starch for steers offered alternative forms of conserved wheat grain

	Diet									
	Grass silage	Crimped & ensiled			Urea-whole			Conventional		
Wheat level	0	Low	Med	*Ad lib.*	Low	Med	*Ad lib.*	Low	Med	*Ad lib.*
Dry matter intake										
Silage (kg/ day)	7.4	5.3	3.7	1.3	5.9	4.6	1.5	5.8	3.9	1.2
Wheat (kg/day)	0	2.5	4.9	7.8	2.4	4.8	8.3	2.4	4.9	8.2
Liveweight gain (g/day)	101	684	887	983	612	724	843	650	868	1043
Kill-out (g/kg)	484	503	502	516	495	502	501	493	511	520
Carcass gain (g/day)	64	421	517	629	351	433	491	362	545	676
Faeces										
Starch, % DM	<1	1	1.5	3.1	5.1	9.9	11.8	1	1.4	2.0

Well preserved, unwilted stemmy (67.9% DMD) silage; Fr. Steers with mean starting liveweight of 518kg, offered diets over duration of 144 days (Stacey *et al.*, 2005).

- Cattle offered grass silage without supplementation had the highest intake of silage DM but the lowest live- and carcass-weight gains.
- Increasing levels of wheat consumption progressively reduced silage DM intake, but increased both live- and carcass-weight gains.
- Cattle offered 'Crimped & ensiled' and 'Conventional' wheat had similar silage intakes, live- and carcass-weight gains.
- Cattle offered 'Crimped & ensiled' and 'Conventional' wheat consumed less grass silage than cattle offered 'Urea-whole' wheat, but had higher live- and carcass-weight gains.
- For steers offered wheat *ad libitum*, grain DM intake was lower with 'Crimped & ensiled' wheat than with 'Conventional' or 'Urea-whole' wheat.
- Cattle offered 'Urea-whole' grain had the highest amount of starch in their faeces, indicating considerable loss of undigested grains.
- Muscle redness was similar for cattle offered each of the three forms of wheat.
- Fat was more yellow when cattle were offered 'Urea-whole' compared to 'Crimped & ensiled' wheat.

Thus:

- 'Crimped & ensiled' could replace 'Conventional' grain in the ration of finishing cattle without compromising performance or meat colour, provided conservation losses for both forms of wheat were properly restricted.

- The large faecal losses of undigested grains resulted in lower growth rates by cattle offered 'Urea-whole' wheat, and this loss in gain got bigger as its inclusion rate in the diet increased (Keady *et al.*, 2005; Stacey *et al.*, 2002,2003a,b,2005).

Alternative forages to grass for grazing
The primary emphasis when feeding cattle in most Irish beef production systems is to maximise the quantity of grazed grass that can be sensibly consumed within sustainable systems. However, grass growth is seasonal, with relatively little growth occurring at soil temperatures below 6°C. In contrast, some brassicas and forage cereals can grow at lower temperatures than this, and produce relatively high yields during the winter period.

Whilst there has been no recent Irish research on alternative crops as winter-feed for grazing beef cattle, ongoing work at Teagasc Moorepark is evaluating rape, stubble turnips and forage oats within dairy systems. Researchers sowed forage rape (cv. Stego; 6.5kg seed/ha) on 3 sowing dates (1, 15 and 31 August) and on each occasion applied 4 rates of inorganic N fertiliser (0, 40, 80 and 120kg N/ha). A second forage rape (cv. Swift) was sown at 6.5kg seed/ha on the 15 August with an application of 80kg N/ha. Stubble turnip cultivars (Delilah, Barkant, Samson and Tyfon) were sown (6.5kg seed/ha) on two sowing dates (1 and 15 August) with 80kg N/ha. On the 15 August, two forage oat cultivars (Stampede and Hokonui) were sown at a seeding rate of 100kg/ha, with 80kg N/ha applied. Each forage was harvested either on 1 December 2005 or 1 February 2006.

To date, Keogh *et al.*, (2006) have shown (Table 11 and Figure 5):

- Winter harvestable yields of 2.8 to 4.9 tonnes DM/ha were achieved. Differences in harvestable DM yield occurred between forages, and between cultivars within forages. The authors concluded that the yields achieved were adequate to support *in situ* grazing during the winter.

- The relativities of the differences between forages and cultivars changed considerably between 1 December and 1 February. Thus, some forages or cultivars appeared more suited than others for providing forage early or alternatively late in the winter.

- An interaction was found between N level and sowing date of forage rape (Stego) - there was an increase of 17.3 and 10.4kg DM/ha/day for every 1kg increase in N applied at the sowing dates of 1 or 15 August, respectively. However, no benefit accrued from N applied to crops sown on 31 August (a reduction of 1.5kg DM/ha/day for every 1kg increase in N applied was recorded).

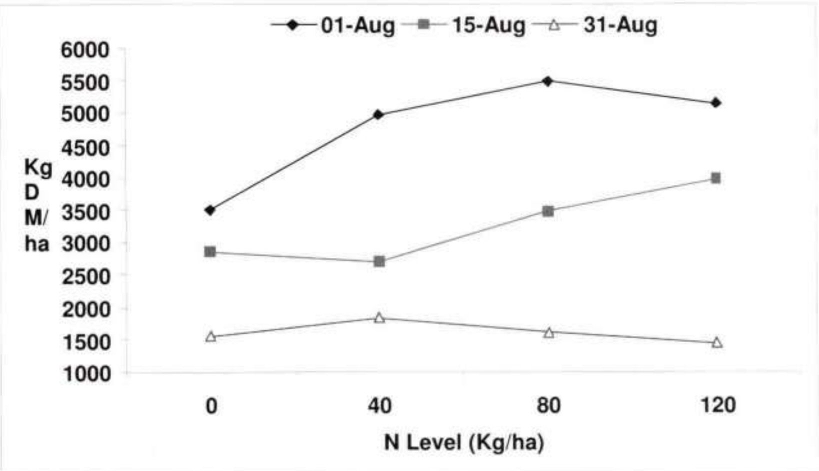
- Sowing date had more of an effect on DM yield/ha of forage rape than N level, with a delay in sowing date beyond the 1 August resulting in a reduction of 735kg DM/ha/week delay

Table 11. The effect of variety and harvest date on total DM yield (kgDM/ha) and morphological components of forages sown on the 15 Aug at 80kg N/ha

Forage	Cultivar	Harvest Date	Total DM yield	Leaf (g/g)	Stem (g/g)	Dead (g/g)
Rape	Stego	1 Dec	3663	0.72	0.17	0.11
		1 Feb	3295	0.67	0.21	0.12
	Swift	1 Dec	3457	0.60	0.24	0.16
		1 Feb	3931	0.59	0.27	0.13
Stubble turnips	Delilah	1 Dec	4930	0.27	0.68	0.04
		1 Feb	4372	0.14	0.78	0.07
	Barkant	1 Dec	4168	0.28	0.56	0.14
		1 Feb	3628	0.20	0.60	0.18
	Samson	1 Dec	3245	0.23	0.55	0.22
		1 Feb	3972	0.16	0.71	0.12
	Tyfon	1 Dec	3248	0.63	0.20	0.16
		1 Feb	2226	0.23	0.54	0.23
Forage oats	Hokonui	1 Dec	2815	0.43	0.37	0.18
		1 Feb	2827	0.31	0.37	0.31
	Stampede	1 Dec	3213	0.37	0.51	0.11
		1 Feb	3693	0.15	0.59	0.25

Source: Keogh *et al.*, 2006

Figure 5. Effect of nitrogen (N) level and sowing date on the DM yield of forage rape (cv. Stego) (Keogh *et al.*, 2006)



In further work, the same researchers offered dry spring-calving dairy cows kale (8kg DM/day), swedes (8kg DM/day) or grass (12kg DM/day), each supplemented with 4kg grass silage DM/day, from 1 December until calving (mean of 20 February). The grazing cows utilised approximately 84, 75 and 65% of the kale, swedes and grass on offer, respectively. It took the cows offered Swedes a considerable period before they started consuming them (almost 3 weeks). However once they became adapted, they progressed very well. A fourth group of similar cows were accommodated indoors and offered excellent quality grass silage *ad libitum* (approximately 77% DMD; no supplement fed). Mean changes in body condition score were +0.17, +0.16 -0.23 and +0.50 for the cows consuming kale, swedes, grass and silage, respectively. There were no significant carryover effects to the subsequent lactation (i.e. subsequent milk yields did not differ).

Further research still needs to be conducted on producing and grazing forages during the winter, with emphasis on the yields and quality produced, the level of intake and performance achieved under different management regimes, and the implications for farm labour, animal welfare, the environment and compliance with various governmental schemes (Keogh *et al.*, 2006).

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Irish Grassland Association 1946-2006 - Delivering the Benefits from Grassland

Sean Flanagan

Introduction

The Irish Grassland Association (IGA) is Ireland's leading forum for discussing the science of grass and animal production, and the economics and finances of dairy, beef cattle and sheep production systems. Membership is 800 and is a lively mix of progressive farmers (70%), research scientists, advisers and agribusiness personnel. The IGA is a member of the European Grassland Federation and has close working relationships with the Ulster Grassland Society, Fermanagh Grassland Club and the British Grassland Society.

This paper contains a summary of the Association's objectives, its activities and technology interactions over the decades, and includes the developments described previously by O'Keeffe (1996). It will be shown that: (a) Research and Development have always been core components of IGA meetings and, (b) the IGA has been a significant driving force in the use of knowledge by dairy, beef cattle and sheep producers for exploiting grazed grass as the cheapest form of feed for ruminant production. In particular, the IGA draws heavily on the skills and knowledge of scientists at the Teagasc research centres, ARINI at Hillsborough, and the Plant Testing Station at Crossnacreevy.

The formative years

Following six years of impoverished farming during World War 2, lack of inputs and knowledge were identified as major constraints limiting successful grassland farming. Basic information on soil fertiliser requirements, grass varieties, reseeding and animal nutrition was non-existent. The New Zealand consultant, George Holmes, brought in by the Minister for Agriculture James Dillon, concluded that Irish grassland in the post-war years was producing significantly less than its potential. However, some pioneering farmers were gathering information to show that Irish grassland was capable of producing significantly more than the limited 5 to 6 months grazing that was customary at the time.

It was against this background that a group of enthusiasts held two meetings in Dublin in 1946; in 84 Merrion Square, Dublin on May 29 and at the Horse Show on July 7, and formed the Irish Grassland Association. The group included progressive farmers, The O'Morchoe, R. McCulloch (Ballyboughal, Dublin), W. Bland (Laois), H.M. Fitzpatrick, - Leonard, J. Litton, W. Bryan and Capt. Redmond together with Professors P.J. Caffrey, M. Gorman, E.J. Sheehy (University College Dublin), and Harry Spain (Department of Agriculture).

Objectives were clearly set:
To identify all available information on grass farming and to help in its application in farm practice.
To advance and spread the knowledge of grassland and animal production methods which can increase farm profits.
To provide opportunities for farmers, research workers and advisers to discuss worthwhile developments in research and farm practice.

To publish original articles or literature on progressive ideas for the advancement of the agricultural industry.

The founders quickly established a pattern of strong relationships and interactions between farmers and research workers. It was accepted at the outset that both were inter-dependant and that each thrived on the others' ability to mutual advantage. This pattern of inter-dependence has been a feature of the Association's progress over the decades and continues to flourish today.

In the early years the Association was dependent on research information from outside the jurisdiction. Useful relationships were established with Aberystwyth (Wales), the Grassland Research Institute (UK), and with pioneering work already underway in Northern Ireland, notably by John Lowe. The IGA invited leading researchers from these sources to its meetings. Progress was made by identifying areas of weakness and arranging visits to the limited research facilities and progressive farms. Existing information was of a very fundamental nature. Factors affecting soil fertility were scarcely understood and represented the greatest limitation to grass growth. Lime was applied infrequently, and clinical phosphate deficiency in cattle existed.

Johnstown Castle
Matters improved in the early 1950s after the Department of Agriculture acquired Johnstown Castle in Co. Wexford. A research programme was established with objectives centred on defining optimum levels of lime and fertilisers for Irish grassland. Production targets for Irish grassland based on measurement were identified for the first time. However, today's view of grassland being fully integrated in a farming system scarcely existed. In those early years of the Association there was a tendency to regard good green grass as an end in itself. However, this attitude did not prevail for long.

Evolution of policy and interests
The President in 1952 (Edward Richards Orpen), instigated change by developing a new policy, - that better farming must be measured by the trend in net profit on a whole-farm basis. Yields per acre or per animal were of little interest unless accompanied by improved net profits. In the evolution of this policy IGA interests became centred on the inter-relationships of animal and pasture on livestock performance.

Responding to the change in emphasis, the Council invited authoritative speakers from overseas institutions to discuss specialised livestock topics - especially dairying. Chief amongst these were Mac Cooper (then at Wye College and later at Newcastle University) who became very much part of the IGA platform; McMeekan from New Zealand discussed low cost performance and whole-farm output without expensive frills, and Alan Stewart from the Milk Marketing Board in England. Stewart told the IGA members that looking at yields of cows was not good enough and that if progress in A.I. breeding was to be achieved, careful assessments and selection of bulls from performance measurements on their daughters were required. Although the IGA had significant impact during the 1950s in providing knowledge and encouragement, it had no impact on animal breeding.

Uncertainties surrounding the conservation of winter-feed presented another bottleneck that bedevilled successful farming. Hay making in Irish weather was always unpredictable. Insufficient winter feed resulted in animal stress in a bad year and produced emaciated cows on dairy farms. At an IGA meeting Henry Kennedy described the condition as 'scientific starvation'. The IGA saw the need for more and better silage and organised visits to the early silage making farms of Rob McCulloch, Sean O'Neill (Lurgan) and elsewhere. Uptake was hampered by confusion on additives and conservation techniques. This situation was soon to change, not alone in silage making but across all sectors of grass farming.

An Foras Taluntais

Following the establishment of An Foras Taluntais (AFT) in 1958 (for which the IGA was a nominating body), its research programme under Director Tom Walsh gave a new impetus to Irish agriculture that continued into the following decades. The pursuit of knowledge and pushing forward the horizons on all sectors of grass farming and ruminant production was a central feature of the AFT programme. For the first time, grass-based livestock production systems were developed based on sound scientific principles and the application of measures of efficiency under Irish climatic conditions.

One of the most significant research outcomes related to maximising the level of N fertiliser use for Irish grassland, and to increasing stocking rates sufficient to consume all grass grown. Research conducted at Moorepark, Grange and Creagh identified the commercial levels of N fertiliser for the appropriate stocking rate in dairy, beef and sheep enterprises. Timing and rates of N applications for grass growth were established at Johnstown Castle, including urea and the role of sulphur. The forage harvester replaced the buckrake. Studies on silage conservation at Grange clarified the factors affecting digestibility, preservation and animal performance, resulting in a consistent and reliable winter-feed.

The development of creamery milk production, beef cattle and sheep output was now underpinned by research and measurement back-up.

EU Entry 1973

In a keynote paper presented at the 1971 Winter Meeting in Cahir, Past-President Michael Walshe described how the current output of Irish agriculture could be trebled, and he quantified the inputs required, including labour, credit and finance. As ever, the IGA platform provoked some straight talking. Weaknesses in Irish agriculture and lack of Government commitment to the development of the very industry that hoped to benefit most from EU entry in 1973 were exposed.

It is of interest to recall 35 years on, that land structure and the exodus from the land were talking points in general circulation then as now. This was evident in the discussion following the address by Dr. Sicco Mansholt, President of the EU Commission at the 25th Anniversary Conference held in Dublin in 1971. The debate was neatly summed up by Past-President Joe Bruton: "We have Michael Walshe telling us about the potential of our grassland, Dr. McMeekan (then with the International Bank for Reconstruction and Development, Washington DC) telling us where the money could come from and now Dr. Mansholt telling us of the product market potential. I don't know what more we want offered to us by way of encouragement, but what we do want is national courage in this country".

Down on the farm, there was an accelerated uptake of AFT information for maximising the opportunities created by EU entry. Capital investment in farm modernisation was huge, rotary parlours were installed for the efficiency of labour, slatted sheds erected and beef cattle feedlots established. Land prices soared, credit was readily available and costs were not a main concern in the context of unlimited markets and high prices. The thirst for R&D information and innovative ideas was clearly evident when over 400 Grassland enthusiasts turned up for the 1973 Summer Tour to Grange/Meath/Louth organised jointly with the Ulster Grassland Society. Sheep production did not develop as an important money making enterprise for another decade due to restrictions in the French market and associated economic factors.

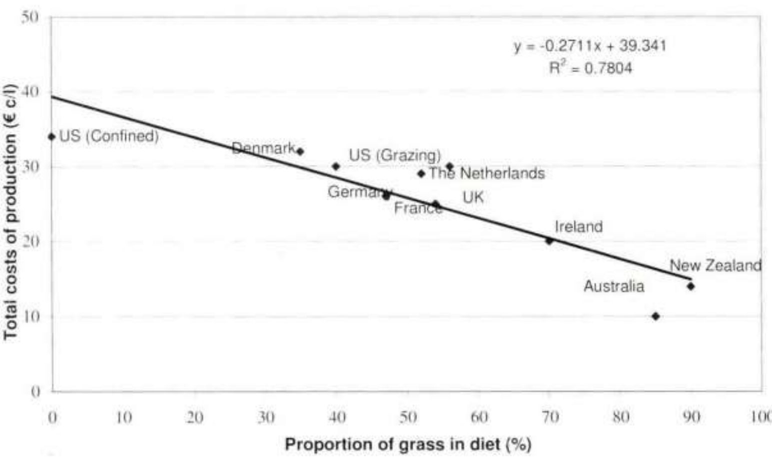
Blueprint for milk production

The following decade was characterised by massive technological change with grassland management improving to the extent that good farmers required only a third of a hectare of land to carry one cow per year. Research at Moorepark developed the following blueprint for milk production: 5150 kg milk output/cow, stocking rate 0.34 ha/cow (1100 gal on 0.85 acres/cow), 1.3 t silage DM/cow, 3.5 t grazed grass/cow, 400 kg N/cow and 650 kg concentrates/cow (P. Dillon *pers. comm.*).

Achieving high dry matter intake

Following the introduction of milk quotas, maximising output from grazed grass became a priority due to the shift in emphasis to maximising profit per gallon with quota being the limiting factor. Constraints to DM intake at pasture, e.g. quality, pre- and post-grazing height and grass allowance became crucial. Research at Moorepark over the last 10 years has developed grazing strategies for increasing the proportion of grazed grass in the cow's diet to 75%, reducing grass silage to less than 20% and concentrate input to 5%. These changes in the feed budget have potential to reduce feed costs by 0.8 cent/litre. Measurement of farm grass cover is a key requirement for implementing these guidelines and the relevant grass cover targets for spring-calving systems have been established. The significance of high DM intake is vividly illustrated in Figure 1. (Dillon *et al.*, 2005).

Figure 1. Relationship between total costs of production and proportion of grazed pasture in cows ration (Dillon *et al.*, 2005)



For the future, due to increased emphasis on product quality and issues associated with nitrogen leaching, soil compaction, gas emissions and animal welfare, higher productivity per animal will be required. Daily grass intake will be maximised by adhering to important sward characteristics such as maintaining a high proportion of green leaf within the grazing horizon while allocating an adequate daily herbage allowance. Increasing the green leaf proportion at the base of the sward may play an important role in increasing herbage intake and making grazing management easier.

Progress in grass breeding has been less than might be expected. Current grass selection and evaluation systems target improved grass DM yields under cutting systems of management rather than animal performance. Although grass breeders have improved DM yields by 0.5% per annum between 1965 and 1990, there is a requirement for an increased grass selection programme focussed on characteristics that influence animal performance, i.e. herbage intake.

Grass breeding in the future will be assisted greatly by new technologies involving gene manipulation, the identification of quantitative loci (QTL) and the use of *in situ* hybridisation to differentially label chromosomes. Careful choice of QTL in market-assisted selection should minimise undesirable correlated responses to selection such as tendency for early spring growth to be associated with early heading and stem development. Use of techniques to genetically modify plants will facilitate the development of plants with elevated concentration of ruminal undegradable dietary protein and high-energy yielding compounds such as starch or triacylglycerides. These are some of the possibilities for future production systems

Grass-based beef systems

Beef cattle enterprises are relatively inefficient when compared with dairying due to lower conversion rates of feed into output and income. At Teagasc Grange, Eddie O'Riordan, Padraig O'Kiely and colleagues tackled the priorities for more efficient measures in beef cattle production, feed cost and in animal breeding. During the period 1980 to 1995 the targets set for suckler calf to beef were advanced progressively from a carcass weight of 340 to 395kg for steers, and from a carcass output/ha of 410 to 500kg/year. Progress was accelerated by innovative farmers who joined the IGA platform and reported on their experiences in commercial practice, including weaknesses, likely solutions and ideas that created valuable feedback to researchers.

Critical reappraisal of the cattle diet generated a new focus on grassland management strategies. The national balance sheet for the proportions of grazed grass, conserved grass and concentrates, expressed as DM intake was: grazed grass 57%, conserved grass 29%, concentrates 14% (McLoughlin, 1991). Costs attributable to the conserved grass plus concentrate components amounted to 70% of total feed costs. It was evident that the economic viability of cattle enterprises is dependent on developing the competitive advantages of grazed grass. As a priority, more flexible grazing procedures were developed to allow for the ever-present fluctuations in grass growth while at the same time utilising the sward in favour of higher animal intake. Measurement of grass supply week-to-week has been adopted as a key requirement for utilising grass to best advantage on the cattle farm. Details on the use of sward height measurements for estimating grass supply and the associated benefits for production efficiency were described in detail at the 50th Anniversary Beef Conference in 1996 (O'Riordan and O'Kiely, 1996), and at the 'Grass Ireland 2000' meeting in Navan (O'Riordan, *et al.*, 2000).

The current targets for suckler beef systems are:-

Standard - 510kg carcass output/ha @stocking rate 0.8 ha/cow beef unit and 200kg N/ha.
REPS - 410kg carcass output/ha @stocking rate 1.0 ha/cow beef unit and 100kg N/ha (Drennan *et al.*, 2004)

Other advances in grassland science include the use of white clover-based swards for achieving high output of beef and palatability evaluations of perennial ryegrass cultivars. Strategic management in spring and autumn has increased the grazing season by 4-5 weeks. High performance from maize and whole-crop cereal silages has been quantified and the appropriate technologies identified. Technologies now being developed to deliver the benefits from grassland include: optimising intake of grazed grass/legume mix over an extended grazing season; quantifying the nutritive value of ryegrasses on the DAF recommended list; improved legume breeding to produce high DM yield and enhanced N fixing abilities.

Outdoor pads for wintering cattle were designed and evaluated successfully to offer a capability for lifting cattle enterprise competitiveness. Their adoption in practice around the country represents present day technology uptake.

Challenges to the sheep sector
In the 1970s the national ewe flock plummeted to less than two million ewes. This was due to limited market access and inferior financial returns compared with dairying or beef. Sheep farming remained in the doldrums until the 1980s when the Common Policy for sheep was implemented. The Sheep CAP heralded a new era, and unprecedented expansion in sheep numbers followed. Profits were second only to dairying.

The delivery of AFT R&D information facilitated growth in output and wealth creation for the sheep sector. AFT Council member and IGA Past-President John Orpen was a prime mover in pushing research on specialised sheep systems as a matter of policy. It was the development of silage-based in-wintering systems that offered farmers a new strategy for rationalising their grass resources with significant knock-on effects: resting of pastures, fertiliser N applications for higher stocking rates and adoption of paddock grazing, resulted in a big lift to the carrying capacity of Irish pasture, up to 15 ewes per ha. Whole-farm grazing systems were set up at Blindwell and Knockbeg to illustrate the principles, i.e. productive pastures well stocked with prolific ewes (litter size 1.9) producing an output of over 400kg of carcass lamb per ha.

However, serious gaps in know-how prevailed, e.g. skills in day-to-day management of large flocks, lamb survival and disease control. IGA initiatives included the annual Sheep Conference first held in 1983. Outside speakers were brought in, notably Bill Fell from Yorkshire, Karl Linklater, VIC, St.Boswells and John Read, a UK Shepherd of the Year. Farm Study Tours to Britain were undertaken with the help of MLC: 1980 Midlands/Lincoln, 1984 Hereford/Chilbolton, 1985 Somerset/Devon, 1986 Cumbria, 1987 Mid-Wales. Uptake of know-how was extensive; the number of flock owners expanded to almost 50,000 and ewe numbers to 5 million.

Changes in CAP in the 90s altered the income relativities of livestock enterprises putting sheep at a disadvantage. The lamb price/feed cost ratio disimproved, decline was triggered and there was a huge cull of nearly 400,000 ewes in 1999 alone. These factors stimulated a new focus on the role of grazed grass for achieving: (a) bottom line production costs and, (b) labour-saving practices. Research at Knockbeg showed that by using grass budgeting principles at stocking rates similar to REPS, extended grazing as a substitute for silage and housing can cut costs per ewe by over 20%. Man hours per day were reduced by two-thirds. Extended grazing is now being practised on a number of commercial farms. Winter housing will continue to be a central component of the intensively stocked system. In tackling the labour issue, a good example of how top farmers have stimulated new ideas was seen at the IGA visit to George Stanley's 800 ewe flock in Laois in 2003. The use of equipment modified for speeding up feeding and day-to-day housing jobs marked new advances in short-circuiting competing demands for time and labour.

Following the 2004 CAP Reforms and decoupling, the IGA linked up with Alistair Carson and his colleagues in Northern Ireland to decide on appropriate response. Jointly with DARDNI, ARINI, UGS and BGS, the IGA organised a 2-day Conference at Greenmount in May 2005 on the theme 'Profit From Your Labour'. Keynote speakers and facilitators including top sheep breeders Lesley Stubbings (Northants), Murray Rohloff (NZ) Alistair Carson, Seamus Hanrahan and John Shirley, outlined their vision for the sustainable development of Ireland's sheep industry. Over 100 IGA delegates participated and departed with positive messages on measures of efficiency for cutting costs and maximising labour returns. One of Rohloff's recommendations has been acted on, i.e. the establishment of the Sheep Strategy Group. Chairman John Malone presented his first report at the IGA 2006 Sheep Conference, pointing out that: (a) Irish processors have capacity to process a higher output into a market that is only 80% self-sufficient and, (b) one-third of producers do not cover the costs of production. Of the various measures outlined there was little mention of our greatest resource, i.e. grass.

The future? The only sheep R&D station in the east of Ireland has been closed. In its place Teagasc is undertaking technology transfer initiatives onto commercial farms, moves that hold promise. The evidence for maximising grazed grass in the diet of the ewe is significant, yet expensive creep feeding continues. Why? The gains in profit from finishing lambs on grass alone were evident at the IGA visit to Andrew Moloney's farm in Edenderry in 2006. What effort is being made to develop and foster skills for estimating how much grass DM is on the sheep farm week-to-week? Can we develop 'easy care' sheep with disease resistant traits? Research at Athenry has identified breed differences for resistance to worm parasites. The use of molecular genetics in breeding for resistance to footrot offers possibilities (Conington *et al.*, 2006). Can a footrot-DNA test appropriate for our breeds be developed? More immediately, the Sheep Strategy Group will be expected to activate measures for increasing the earning power of the 35,000 producers who remain dependent on sheep for income.

Submissions on agricultural policy

Responding to changes in current agricultural policy as they take shape, the IGA has engaged in discussion with the policy makers of the day in government and submitted its proposals in the interests of a vibrant and sustainable Irish agriculture. Submissions included:

In 1987, 1999 and 2003; cutbacks in Teagasc Research
In 1999; Agric-Food 2010 Committee
In 2001, 2004 and 2006; Nitrates Directive
In 2001, then President Noel Culleton forewarned the IGA on the damaging effects to Irish agriculture of the Nitrates Directive.
In 2003; Milk Quotas

Strategic reviews
With on-going changes in EU policies and in the national economy, the IGA has conducted periodic reviews of its aims and vision, its organisation, and responses to new opportunities, led by the President of the day, notably Padraig O'Kiely, Matt Dempsey, Pat McFeely, Con Hurley and John O'Brien. Issues subjected to scrutiny include:

How best to address the needs of the membership as changes occur in the national economy.
Review of the IGA platform as a debating forum especially with policy makers.
Planning for future initiatives to provide leadership to the industry.
Improving the presentation and delivery of the papers presented at its conferences.
Increasing the membership including corporate membership.

Fundamental questions
In keeping with its role for vigorous dialogue, some stark messages have been delivered from the IGA platform in recent years. In particular, at the 2000 September meeting, Michael Murphy argued that the agricultural industry had no clear vision for the future. He was strongly critical of the performance of the institutions and farm service agencies surrounding Irish agriculture, the rigidity of the milk quota regulations and lack of innovation in milk processing and marketing. His message was that "nine out of ten farmers will either be out of business or living in poverty within 10 years" and asked "Where are the people to plan and implement constructive change"? He urged all segments of the industry to come together and agree a vision to secure the future, develop a vibrant industry, provide opportunity for new entrants and prosperity and a future for Irish farmers. "I wish in 10 years time to be part of a positive, dynamic, growing industry, which is highly competitive internationally and giving good incomes and careers to people at all levels of the industry".

The debate continues with significant contributions from Mike Magan on priorities for turning around the steady erosion of profit margin on-farm.

International Grassland Congress
The world's grazing lands consist of 3,000 million ha of grassland, most of which is utilised by livestock for feeding the world's populations. The IGC is the premier world event for grassland R&D, a forum for authoritative analyses on world food production and on new technologies for utilising grasslands for the benefit of mankind. It is held every four years.

With the build up of R&D information in Ireland and associated grassland impetus in the 70s, the Council recognised the potential benefits of bringing the Congress to Ireland. At the XII Congress in Moscow in 1973, the IGA submitted a bid that had world-wide support, but in the event lost out to Leipzig in East Germany for 1977. The IGA then took the opportunity to activate a follow-on event to the Leipzig Congress, namely, an International Meeting on the theme 'Animal Production from Temperate Grassland'. President Jim

O'Grady in association with Aidan Conway and AFT headed up the organisation of this event held in the RDS, Dublin, June 5-12, 1977. Twenty-one leading researchers were selected to present plenary papers focussed on temperate grass growing conditions, with 53 offered papers and study tours. 365 delegates from all temperate zones including those in South America participated.

In 1997 at the XVIII IGC in Canada, BGS and IGA delegates Roger Wilkins and the author agreed to explore the feasibility of making a joint UK/Irish bid to host the XX IGC in 2005. The bid, compiled by Dr John Walsh for IGA with the theme 'Grassland – A Global Resource', was successful. The management of the Congress was delegated to a special Organising Committee anchored by Dr Frank O'Mara (UCD) and included representatives from IGA, BGS, Teagasc, DAFF, DARDNI and UCD. The core programme as held in UCD Belfield on June 26 – July 1 2005 including the Jan Crichton Producer Forum that featured a paper by IGA Past President Jim Dwyer. Satellite Workshops were held as an integral part of the Congress at Aberystwyth, Belfast, Cork, Glasgow and Oxford. The Congress attracted over 1100 delegates worldwide including 95 from Ireland.

European Grassland Federation

The EGF facilitates close contacts between European Grassland Organisations by initiating symposia, etc. and promoting interchange of scientific ideas and results. Currently, Eddie O'Riordan at Grange is IGA representative. A 4-day general scientific meeting is held every two years. Following an invitation by Aidan Conway, then President of EGF, the IGA hosted the 12th General Meeting of the European Grassland Federation in UCD Belfield on July 4-7 1988. Ten Plenary papers together with 76 Offered papers were presented. 223 delegates from 22 European countries including 46 from Ireland participated.

British Grassland Society

The Summer Meeting of the BGS is regarded by many as its main event. It consists of three full days of farm study visits and AGM. The Meeting has been hosted by the IGA on two occasions, in 1964 in Meath/Kildare/Cork and in 1992 in Cork, led by Eamonn White and Con Hurley as Host Vice-Presidents, respectively. The theme in 1992 was 'The Cork Grass Mixture: Research + Practice + Profit. Study visits to Moorepark and to grass farm enterprises specially selected for innovative and profitable systems were arranged. 199 BGS members participated.

Joint meetings – Grass Ireland 2000

To mark the new millennium, the IGA in association with the UGS, Fermanagh Grassland Club and South Armagh Grassland Club organised two Meetings in Tullamore and Navan to gather and update the membership on: (1) the latest R&D grass-related information north and south; (2) EU Policy and, (3) producing cattle for Europe. Franz Fischler, EU Commissioner for Agriculture, was the keynote speaker in Tullamore.

Administration

Working at the heart of the Association, the administrative, secretarial and financial expertise of Madeleine Flanagan and Grainne Dwyer have been essential components for the IGA's progress. This review would not be complete without expressing due recognition and tributes. Quite apart from the smooth running of the substantial calendar of events, dealing with day-to-day queries and promoting IGA interests, the financial health of the Association has been largely due to their stewardship.

Donegal Organising Committee
In an area noted for its progressive farming, a number of grassland enthusiasts in east Donegal led by Neville Chance asked for approval from the IGA Council in the 60s to form a sub-committee for the purpose of arranging Grassland meetings locally. Distance plus the difficulties of getting away for two days or so to participate at meetings in the south were cited as reasons. The Council agreed and also that all participants be fully paid-up members. The committee with Neville Chance in particular was very active and successful. Two meetings were held annually in Raphoe and there was a close affinity with Northern Ireland interests. The committee hosted the IGA Summer Meeting on a number of occasions, notably in Derry and east Donegal in 1970, against the backdrop of the Troubles. Members got a front-seat view of the problems when the bus driver took a wrong turn in Derry city. Neville passed away in 1994 and committee interest was overtaken by newly formed discussion groups and agri-business meetings.

Association Journal
The IGA's Journal was launched during the 60s principally through the efforts of Vivian Vial, senior AFT researcher and IGA Council member, who recognised more than most the importance of publishing the papers that contributed to the development of IGA thinking. He saw the annual proceedings as a medium for the dissemination of authorative and enlightened ideas. He was succeeded from 1973 to 2000 by the author who collated and edited all suitable papers. David McGilloway has taken over the editorial work since 2000. Requests from overseas libraries indicate awareness of research developments and progressive farming in Ireland and recognition of the role of the IGA in reporting this progress. It also provides a permanent record of useful reference material for farmers and students.

Agricultural Research Forum
In 1970, to provide opportunities for scientists to read short technical papers and to exchange ideas, the IGA initiated a one-day seminar held twice annually in Dublin. It was organised by Sean Crowley initially, followed by Jim O'Grady and later by Padraig O'Kiely. It was expanded to two days in 1994 and jointly with the Irish Tillage and Land Use Society, Soil Science Society and the Agricultural Economics Society, it operates under the umbrella 'Agricultural Research Forum'. The number of papers including posters has grown to 135 in 2006 presented in three simultaneous sessions. Micheal Diskin has chaired the Organising Committee since 2001. Ann Gilsenan at Grange provides the highly valued administrative back-up. Held in Tullamore, the Forum has become a core event in the researcher's annual calendar.

Summary
The IGA has provided an independent forum for discussing new information, technologies, farm practices and policies and for stimulating new ideas.
Members are provided with opportunities to discuss the latest cutting edge information and ideas that can increase farm profits.
Grass will continue to be Ireland's main competitive advantage for ruminant production.

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