Beef-cattle production: feed efficiency

Mark McGee BAgrSc PhD, Eddie O'Riordan BAgrSc PhD, David Kenny BAgrSc PhD, and Aidan Moloney BSc PhD, Teagasc, AGRIC, Grange, Dunsany, Co Meath, outline the recent developments in cost-efficient feed for beef-cattle production

In beef-production systems, feed provision accounts for the single largest direct cost incurred by beef producers, accounting for approximately 75% of total costs of production; therefore, small improvements in feed efficiency (FE) can have a relatively large influence on farm profitability. Additionally, feed-efficient cattle excrete fewer nutrients, and produce less gaseous emissions, to the environment. Consequently, there is considerable interest internationally in feed efficiency as a means of improving the economic and environmental sustainability of beef-production systems. There are many different contexts, approaches and measurements of feed efficiency in beef-cattle production ranging from a focus on the individual animal to the full-production system operated. A series of recent experiments carried out at Teagasc Grange, funded by the Department of Agriculture, Food and the Marine (DAFM) research stimulus fund (13/S/519; 11/SF/322; 11/S/122), have evaluated various aspects of feed-efficient beef-cattle production.

ANIMAL FACTORS

VARIATION IN FEED EFFICIENCY WITHIN CATTLE POPULATIONS

In the context of the animal, traditionally, feed conversion ratio (FCR – feed: gain) or its inverse, feed conversion efficiency (FCE – gain: feed), was the feed-efficiency measurement of choice. However, the use of FCR in cattle-breeding programmes generally leads to selection of faster-growing animals that have a larger mature size and thus, a higher overall feed requirement. This has negative ramifications, particularly for the cow component of suckler-beef production systems because of their proportionately higher (overhead) costs.

In essence, if an increase in feed requirements of the breeding cow herd offsets gains in growth efficiency of the progeny, there will be no gain in overall production system efficiency. As a result, there has been much interest, worldwide, in examining alternative feed efficiency traits

such as residual feed intake (RFI). The concept of RFI, rather than FCR or FCE, is becoming the preferred measure for the genetic selection of animals with improved feed efficiency across many livestock production enterprises, and, in particular, for beef cattle.

Cattle with low RFI (efficient) consume less feed than expected based on their weight and growth. The advantage of using RFI as a means of identifying and selecting for improved feed efficiency is that it is independent of growth rate and body size, ie. the ability to select for feed-efficient cattle without increasing mature size.

Research at Teagasc Grange has shown that in any group of growing cattle or suckler cows – within breed type – there can be up to >20% difference in the feed consumed by the most efficient compared to the least efficient animals for the same level of growth and performance (eg. Lawrence et al, 2011, 2012, 2013; Fitzsimons et al, 2014a, 2014b).

These feed-efficient cattle also produce less methane, due to their lower feed consumption (Fitzsimons et al, 2013). However, evidence from recent Grange studies, shows that the ranking of beef cattle for feed efficiency offered the same diet is not necessarily consistent over different phases of their lifetime, and this may be further exacerbated when different diets are fed successively (ie. forage versus concentrate-based diets), as per commercial farming practice (Coyle et al, 2016a, 2016b, 2017). This re-ranking seems to be especially apparent for the more conventional measures of feed efficiency (ie. FCR and FCE) compared to RFI. This strongly indicates the presence of what is termed a 'genotype x environment' interaction for the trait; in other words, that the relative feed efficiency of a particular animal depends on the type of feed it is offered or management system within which it is reared.

Clearly, feed efficiency is a multifactorial and complex trait in beef cattle and inter-animal variation stems from the interaction of many biological processes influenced, in turn, by physiological status and management regime (Fitzsimons et al, 2017; Kenny et al, 2018). Due to the logistical difficulty and considerable expense associated with measuring the feed efficiency potential of individual animals, the challenge now is to reliably and cost-effectively identify feed-efficient cattle, such as by using robust biomarkers to assist genetic selection, and proliferate their genetics through structured animal breeding programmes.

DAIRY VERSUS BEEF BREEDS: DIFFERENCES IN PERFORMANCE AND FEED EFFICIENCY

Due to the abolition of milk quotas in the European Union, expansion of the Irish dairy herd has meant that proportionately more beef is now derived from dairy-bred compared to beef-bred animals. In this context, the intake, performance and feed efficiency of suckler-bred compared to dairy-bred cattle is of interest. A recent Grange study comparing Charolais (3/4 bred or greater) with Holstein-Friesian steers individually offered zero-grazed grass indoors found that, despite the fact that the Holstein-Friesian were 80kg lighter and growing significantly more slowly during the test period, they consumed 4% more grass-dry matter (DM) daily resulting in a 10% poorer FCE compared to the suckler-bred Charolais (McGee et al, 2018b).

Likewise, in the finishing phase where the two breed types were offered a high-concentrate diet, the older, lighter, slower-growing Holstein-Friesian steers consumed 10% more feed DM resulting in a 20% inferior FCE (McGee et al, 2018c; see Table 1). Carcase fat score was similar for both breed types but kill-out proportion and carcase weight and conformation score was considerably inferior for the Holstein-Friesian compared to the Charolais (see Table 1).

	Charolais	Holstein-Friesian	Significance
Age: start of finishing (days)	654	678	***
DM intake (kg/day)	11.5	12.6	***
Live weight, mid-test (kg)	726	659	***
ADG (kg)	1.34	1.27	P=0.07
FCE (kg live weight/kg DMI)	0.12	0.10	***
Carcase weight (kg)	442	360	***
Kill-out proportion (g/kg)	617	519	**
Carcase conformation score (1-15)	10.3	4.5	***
Carcase fat score (1-15)	9.9	9.9	NS

Source: McGee et al, 2018c.

Table 1: Age, intake, daily live weight gain (ADG), feed conversion efficiency (FCE) and carcase traits of suckler-bred Charolais and Holstein-Friesian steers offered a high-concentrate finishing diet.

Likewise, a previous study at Grange comparing Holstein/Friesian and late-maturing suckler-bred cattle (slaughtered as bulls at 15 months of age or as steers at 24 months of age) showed that overall, the beef breeds gained about 23% more live weight during the finishing period per unit of feed energy consumed compared to the dairy breeds (Clarke et al, 2009). However, because of the higher kill-out proportion and the greater proportion of meat in the carcase of the suckler-bred beef cattle compared to the dairy breeds, the percentage of meat produced per unit of energy consumed was on average 51% greater for the beef than dairy breeds. Clearly, this breed difference in feed efficiency is a substantial cost to the beef farmer.

BULLS VERSUS STEERS: DIFFERENCES IN PERFORMANCE AND FEED EFFICIENCY

Research in Grange and elsewhere has shown that males produced as bulls are superior to steers of similar breed, reared under similar management on the same diet and slaughtered at the same age, for growth, carcass weight and conformation score, and lean meat yield (O'Riordan et al, 2011). Bulls are also inherently more feed-efficient, 10-20% better, than comparable steers (O'Riordan et al, 2011). However, most published information derives from confined systems, often with high-concentrate inputs. How bulls and steers compare on lower-cost, grass-based production and finishing systems is relatively unknown. An important caveat with bull-beef production is that producers should always

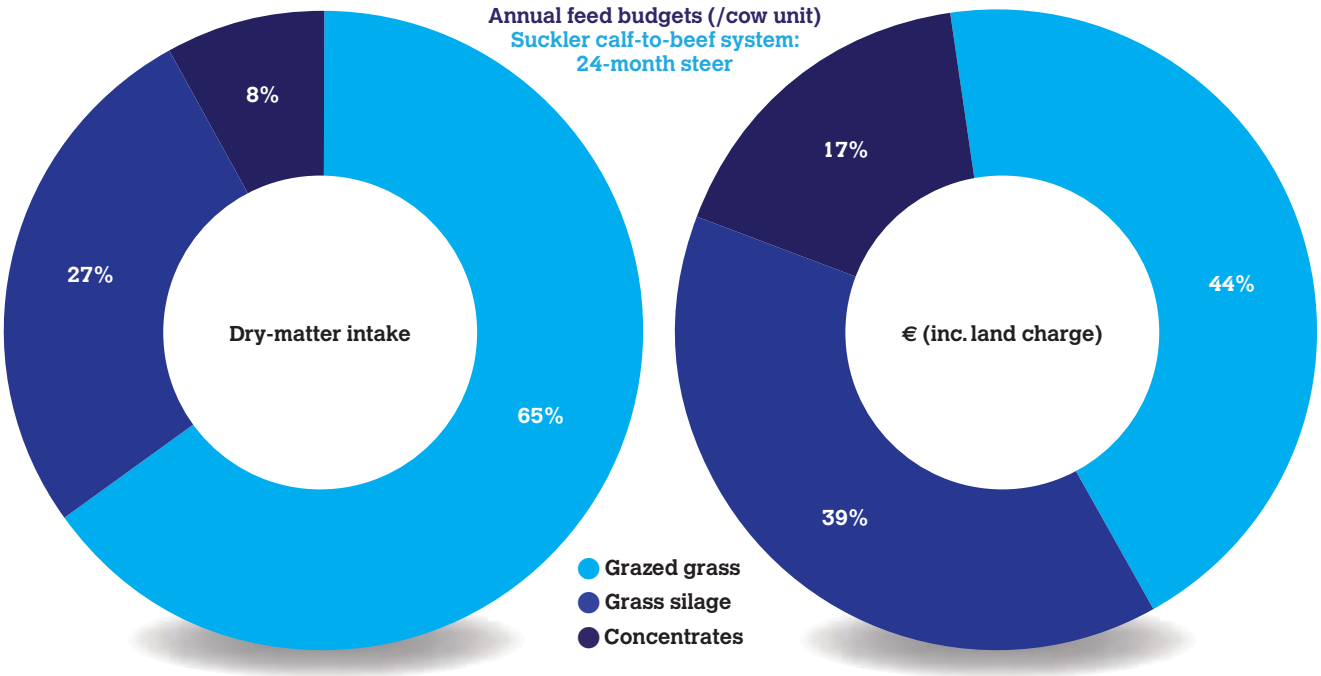

Figure 1.

discuss market options in advance with their meat processor, as markets may be limited.

GRASS-BASED PRODUCTION SYSTEMS: SUCKLER-BRED CATTLE

Within beef production systems the primary feed costs relate to the indoor/winter feeding periods, and particularly feeding of finishing cattle. Therefore, enhanced feed (cost) efficiency at these times has a comparatively greater financial impact. For example, grazed grass, grass silage and concentrate account for 65%, 27% and 8% of feed DM intake annually, respectively, in grass-based, suckler calf-to-steer beef systems on research farms. When this feed consumption is expressed in terms of cost (land charge included), the outcome is very different: grazed grass, silage and concentrate account for 44%, 39% and 17% of the total annual feed costs, respectively (see Figure 1).

	Concentrate feeding level (kg/day)			
	2	4	6	Sig.
Silage DM intake (kg/d)	4.8a	4.0b	3.6c	***
ADG indoor first-winter (kg)	0.67a	0.91b	1.18c	***
ADG pasture (kg)	1.17a	0.88b	0.87b	***
ADG indoor-finishing period (kg)	1.81	1.99	1.85	P=0.10
ADG post-weaning to slaughter (kg)	1.09	1.12	1.15	NS
Turnout-to-pasture weight (kg)	454a	484b	517c	***
48h post-turnout-to-pasture weight (kg)	438a	465b	490c	***
Housing weight (kg)	553a	550a	574b	***
Slaughter weight (kg)	709	715	703	NS

Source: Marren et al, 2013.

Table 2: Effect of first-winter concentrate feeding level on intake, ADG and carcase traits of suckler bulls.

COMPENSATORY GROWTH

Compensatory growth is the ability of an animal to undergo accelerated growth when offered unrestricted access to high quality feed after a period of restricted feeding or under-nutrition.

In order to reduce feed costs, exploitation of this biological phenomenon is recommended for feeding weanlings (or store) cattle over the expensive indoor winter period following which, they are turned out to pasture in the spring to graze cheaper produced grass.

Put simply, there is little point in 'over-feeding' weanlings in winter as, during the subsequent grazing season, cattle that gained less over the winter have the highest live weight gain at pasture. For steers (and heifers) the target growth rate over the indoor winter period is ca. 0.5-0.6kg live weight per day (eg. McGee et al, 2014). Recent research at Grange has shown that this target winter growth rate similarly applies to weaned, high-growth potential suckler bulls (Marren et al, 2013; McMenamin et al, 2014; see Table 2). Exploitation of compensatory growth at pasture is therefore, a means to reduce winter feed costs within grass-based bull-beef systems (O'Riordan et al, 2011).

PASTURE-BASED 'FINISHING' IN AUTUMN: EFFECT OF BREED TYPE, GENDER AND SUPPLEMENTATION.

The early-finishing of spring-born, suckler-bred steers (and bulls) at ca. 19-20 months of age from pasture, prior to housing for a second winter, eliminates the need for an expensive indoor finishing period. However, a key challenge is 'finishing' late-maturing breed cattle, the predominant breed type nationally, from pasture, and because achieving an adequate carcass fat score (ie. >2+ or >6 on a scale of 1-15) is a primary market requirement, this is critical. As breeds differ greatly in their propensity for fat deposition (Moloney and McGee, 2017), early-maturing beef breeds (eg. Angus, Hereford) may be more 'suitable' for grass-

based finishing systems compared to late-maturing beef breeds (eg. Limousin, Charolais). Additionally, there may be a role for strategic concentrate supplementation at pasture to enhance feed-nutrient intake and thus, subcutaneous fat deposition.

In this context, a series of recent grazing-based experiments carried out at Grange using **spring-born, suckler-bred** cattle has established that:

- When finished from pasture at the same age, ca. 19 months:
  - Carcases from early-maturing breeds were lighter, fatter, and had poorer conformation than late-maturing breeds (Regan et al, 2017, 2018b).
  - Bulls had greater growth, live weight, better kill-out proportion, a heavier carcass, better carcass conformation score and a lower carcase fat score than steers (Regan et al, 2018a; McGee et al, 2018d).
- Early-maturing breed steers were adequately 'finished' at 19-20 months of age from unsupplemented pasture in all experiments, whereas late-maturing breed steers were finished in some (Marren et al, 2014; Regan et al, 2018a) but not other (Regan et al, 2018b) experiments. The inconsistency across studies in achieving adequate carcass fat score was likely attributed to inclement, weather-related, grazing conditions having an adverse effect on intake and performance.
- Concentrate supplementation during the latter half of the grazing season (ie. ca. 4-5kg daily for 75-95 days) increased carcase fat score of steers at pasture (Marren et al, 2014; Regan et al, 2018a); supplementation is a possible strategy for finishing late-maturing breed-suckler steers from grass at ca. 19-20 months.
- Compared to late-maturing breed steers, carcases from late-maturing breed bulls were only adequately finished at 19 months of age when supplemented with concentrates (ie. ca. 4kg daily for 95 days [Regan et al, 2018a).
- Carcases of early-maturing breed bulls slaughtered at 19 months of age from pasture were lighter but adequately finished, with or without concentrate supplementation during the latter half of the grazing season (ie. ca. 4kg daily for 95 days), whereas the heavier, late-maturing breed-bull carcases were only adequately finished when supplemented (Regan et al, 2017).
- Carcases of both early-and late-maturing breed suckler bulls were inadequately finished from pasture, with or without concentrate supplementation at 15 months of age (McMenamin et al, 2015; Lenehan et al, 2017a).

Collectively, these findings indicate that spring-born, early-maturing breed suckler steers can be finished from well-managed pasture in autumn at ca. 19-20 months of age without concentrate supplementation, whereas late-maturing breeds may need supplementation.

Spring-born, early- and late-maturing breed-suckler bulls produced from pasture under 16 months of age are unlikely to meet market-specific requirements in terms of carcase fat cover, even with moderate concentrate supplementation; however, this carcase fat target (2+) is achievable from well-managed pasture at ca. 19-20 months of age without concentrate supplementation for early-maturing breeds, and with moderate levels of concentrate supplementation for late-maturing breeds.

CONCENTRATE FEED INGREDIENTS

Feeding concentrates is a key component of beef production systems, especially during indoor winter periods and the finishing period. The primary role of concentrates is to make up the deficit in nutrient supply from forages to allow cattle reach performance targets. Indoor feed costs could be reduced through utilisation of alternative (more cost-effective) feed ingredients.

In addition to cereals, a wide variety of feed ingredients is available and used extensively in beef rations. By-product feeds, also known as co-products, are secondary products mainly from the food processing industry and the biofuel/ethanol industry.

By-products generally have little value as a foodstuff for humans, but many are suitable as a feed for cattle due to the ability of cattle to digest fibrous, plant cell-wall material. However, a potential limitation of feeding by-products to cattle is that significant variation can exist in their chemical composition and nutrient content, and this is liable to change over time as the primary manufacturing processes evolve and become more efficient. This means that periodic re-evaluation of the nutritive value of by-products is required for accurate formulation of feedstuffs for beef cattle.

In this context, a series of recent experiments carried out at Teagasc Grange, has evaluated a number of key cereal and by-product feed ingredients in beef-cattle diets. The 'control' concentrate offered in all these studies was a barley/soyabean meal-based ration (ca. 862g rolled barley, 60g soya bean meal, 50g molasses, 28g minerals and vitamins/kg); all other rations were compared against this. The optimum inclusion level of a number of by-product feeds was evaluated by replacing rolled barley (and some, or all, of the soyabean meal depending on the protein content of the test feed ingredient) in the ration. All concentrates were prepared as coarse mixtures. Key findings are as follows:

- Carcase weight was heavier and feed efficiency was better in bulls offered a high-concentrate diet where half of the rolled barley in the control ration was replaced with maize meal, but not flaked-toasted maize; maize inclusion in the ration did not enhance carcase-fat deposition (Lenehan et al, 2015a).
- Rolled oats can replace rolled barley in a concentrate supplement (ca. 5.0kg/day) to high-digestibility grass silage without negatively affecting performance of finishing beef cattle; feeding oats had no effect on carcass fat score (McGee et al, 2018a).
- For growing 'weanling' cattle, soya hulls and citrus pulp can replace rolled barley in concentrate rations offered at relatively low levels (ca. 2kg/day), as a supplement to high digestibility grass silage, without negatively affecting performance (Lenehan et al, 2015b; 2017b).

- For finishing cattle diets, citrus pulp can replace rolled barley in the ration at inclusion rates up to 400g/kg without negatively affecting performance when offered ca. 5kg concentrate per day as a supplement to high digestibility grass silage (Kelly et al, 2017).
- For growing cattle offered ca. 3.5kg/day of concentrate as a supplement to moderate digestibility grass silage, and finishing cattle offered *ad libitum* concentrates, the optimum inclusion level of soya hulls in a barley-based concentrate was ca. 200g/kg (Magee et al, 2015c).
- Dried corn gluten feed had a feeding value comparable to that of rolled barley/soya bean meal when offered as a supplement (ca. 5kg/day) to high-digestibility grass silage (Kelly et al, 2018).
- Maize-dried distillers grains had a superior feeding value (based on dietary feed conversion ratio) to wheat dried distillers grains when the ration was offered as a supplement (3.5kg/day) to grass silage or *ad libitum*. The optimal inclusion level of maize and wheat dried distillers grains in the concentrate was about 800g/kg when the concentrate ration was offered as a supplement to moderate digestibility grass silage and, about 400g/kg for maize, and 200g/kg for wheat, dried distillers when the ration was offered *ad libitum* (Magee et al, 2015a; 2015b).
- Palm kernel expeller meal can be included in a barley-based concentrate at up to 400g/kg when offered as a supplement to moderate digestibility grass silage and up to 100 g/kg when offered *ad libitum* (Magee et al, 2016).

Overall, it is concluded that, the feeding value of by-product feed ingredients is a function of their inclusion level in the concentrate and whether the concentrate is offered as a supplement to grass silage or to appetite with restricted grass silage.

These findings imply that 'associative effects' between grass silage and concentrate feed ingredients have consequences for feed utilisation and thus, the nutritive value assigned to by-product feed ingredients. This means that the relative economic value of by-product feed ingredients is contingent on concentrate-feeding practices. Together, the results show that beef farmers, and the animal feed industry, have the opportunity to source alternative (cost-effective) feed ingredients as supplements to grass silage.

REFERENCES ON REQUEST