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Beef Feed Efficiency Programme Consortium Update

March 2020

1. Current position

The Beef Feed Efficiency Programme (BFEP) completed its data collection phase in early March 2019, which was a further major milestone. The data was finalised and assimilated by SRUC ahead of their final analysis and reporting phase, which has also been completed. The final detailed report and a summarised report for public access have been submitted to DEFRA and approved. Additionally, a final set of protocols have been finalised, for public access. Currently we are preparing dissemination tools, along with some practical metrics and assisting creation of Estimated Breeding Values (and GEBVs) for roll out in the Limousin breed.

2. Key Messages

- A lasting infrastructure for measuring feed efficiency in UK commercial beef cattle population has been established, and that subsequent data can be incorporated into breed improvement programmes through the generation of genetic parameters for the Limousin breed, and industry protocols.

- Genetic parameters for Limousin population have been calculated for all traits influencing feed efficiency based on data collected in UK commercial conditions, including heritabilities, correlations and updated economic weights. Generation of EBVs and GEBVs for feed efficiency is now possible for the Limousin breed. Heritabilities were high for growth traits, and moderate for feed intake traits – 0.35 – 0.40, whereas the remaining fat depth traits and RFI were low (<0.10), but in line with other literature.

- Combined analysis (Limousin and Angus) shows that the heritability for feed intake traits are 0.24, 0.35 and 0.46 for RFI, ADG and DMI respectively, with moderately high genetic correlations between these traits (0.56-0.92). Heritabilities for carcase traits were 0.35 (net carcase weight), 0.06 (Conformation), and 0.03 (fat class) with net carcase weight being within the expected range but conformation and fat class lower than expected.

- Introducing selection for feed efficiency into routine breeding programmes (selection indexes) has the potential to increase the economic response by 40% to £43.4 million (compared to current indexes - £30.9 million) – an increase of £12.5m -expressed over 20 year horizon assuming 10 years of continued selection.

- There is estimated to be an increase in the reduction of GHG savings of 27% over the same time period due to the reduction in feed consumed and digested.

- The annual (and cumulative) economic response per breeding cow is estimated to be £2.95, which compares with £2.10 without including RFI in the breeding goal – an increase in £0.85 per cow.

- In practice, a difference of 1.8kg DMI was shown between the top and bottom 10% of the individuals measured. This equates to a feed saving of £0.23 /hd/day, or £27.60 /hd over a 120-day finishing

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period. On a unit finishing 750 head per year, this represents a saving of £20,700 per year. Further, this also represents a reduction in fodder (or grazing) requirement of 151 kg per hd or 3 ha less ground required to sustain each animal. Alternatively, stocking density can be raised to support more animals per hectare.

3. Results summary

Cattle were fed ad libitum across 5 units between Dorset and Forfar, with feed intakes measured for 63 days and cattle weighed weekly. Of these, 2434 animals exhibited linear growth and the data from these animals were analysed to estimate feed intake measurements and estimate genetic parameters. Overall the mean age of cattle starting trial was 337.3 days (~11 months) and the mean weight was 384.9 kg. During the trial period the mean weight gain was 81.2kg or 1.3kg per day. The mean daily dry matter intake (DMI) was 8.3kg and the mean feed conversion ratio was 6.7kg.

Heritability estimates for the Limousin breed were high for weight traits (>0.7), eye muscle depth, growth rate and DMI were moderate (0.35 – 0.40) whereas the remaining fat depth traits and RFI were low (<0.10) and lower than expected. Estimates were similar when a sire model was employed, and this included estimates for net carcase weight and age at slaughter which were 0.40 and 0.30 respectively.

Data was collected on 485 (useable records) Aberdeen Angus steers, which originated from 95 sires. The dataset was considered too small to estimate genetic parameters accurately.

However, the Angus records were used in a combined breed (Limousin and Angus) analysis with the aim of creating genetic parameters from the total of 396 sires. A summary of descriptive statistics for combined sire-breed dataset is shown in Table 1.

Table 1. Combined dataset - Descriptive statistics for age, weight, ultrasonic, feed efficiency and carcase measurements

Trait/covariates	Min	Max	Mean	s.d	Count
Initial mean fat depth (rib and lumbar) (mm)	0	9.375	1.8	1.25	2431
Final mean fat depth (rib and lumbar) (mm)	0	13.125	3.3	1.80	2434
Final eye muscle depth (mm)	38	95	64.9	8.76	2432
Mean dry matter intake (kg)	3.5	16.7	8.3	1.71	2434
Feed conversion ratio	3.14	16.89	6.7	1.87	2434
Residual feed intake	-3.93	8.10	0.00	1.34	2434
Average daily gain (kg/day)	0.322	2.255	1.30	0.30	2434
Net weight (kg)	247.4	518.03	346.5	39.66	1339
Conformation (1-15)	4	14	8.4	1.96	1339
Fat (1-15)	2	13	9.1	1.65	1339

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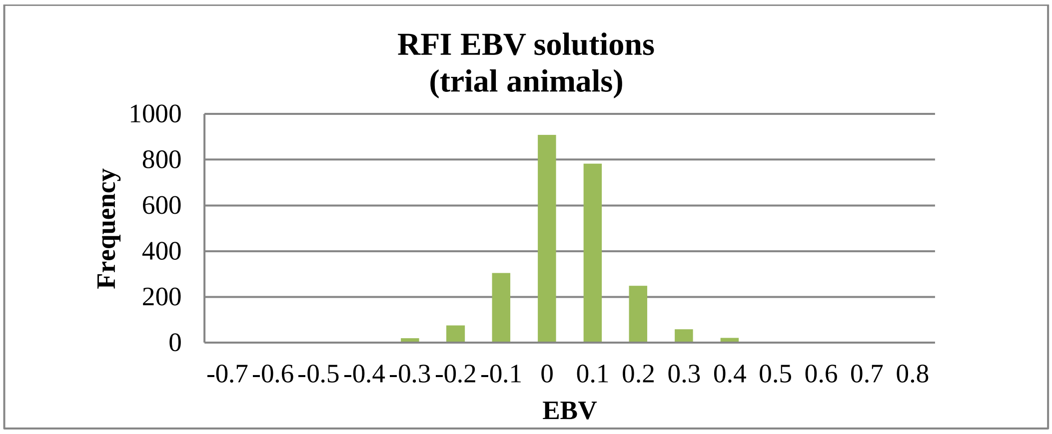
Table 2. Genetic parameter estimates of bodyweight, ultrasonically scanned and feed efficiency traits using both animal and sire models

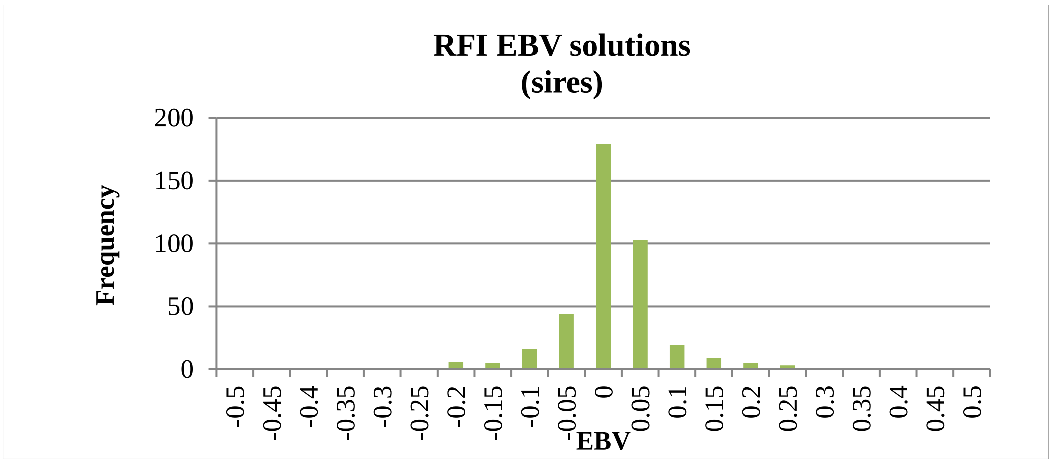
	Heritability (Animal Model)	Heritability (Sire model)
Final mean fat depth (rib and lumbar)	0.19 (0.118)	
Final mean fat depth (rib)	0.13 (0.104)	
Final mean fat depth (lumbar)	0.20 (0.123)	
Final muscle depth	0.29 (0.128)	
Residual Feed Intake	0.23 (0.116)	0.24 (0.117)
Average daily gain	0.35 (0.135)	0.35 (0.132)
Dry matter Intake	0.39 (0.132)	0.46(0.14)

Heritability estimates were moderate for eye muscle depth and feed efficiency traits (0.23-0.39) and low to moderate for fat depth traits (<=0.20). The sire model shows heritability estimates for feed efficiency traits RFI, ADG and DMI were moderate (0.24-0.46). Genetic correlations between RFI, ADG and DMI were moderate to high (0.56 – 0.92).

Figure 1 shows the distribution of RFI for both trial animals and their sires. It would be expected that the majority of the population would be distributed around zero given that the measurement is the difference from the predicted intake, which would be expected to be zero on average.

Figure 1. Distribution of RFI EBV's for trial animals and sires





The report concludes that there are positive genetic correlations between RFI and other traits examined, which would suggest that progress may be harder than first expectation, however by plotting the EBV solutions of

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animals, shown in Figure 2, it can be seen that there are some animals that have a favourable combination of RFI and other traits – found in the bottom right quadrant – so selection progress can be made.

Figure 2. EBV solutions for conformation and RFI

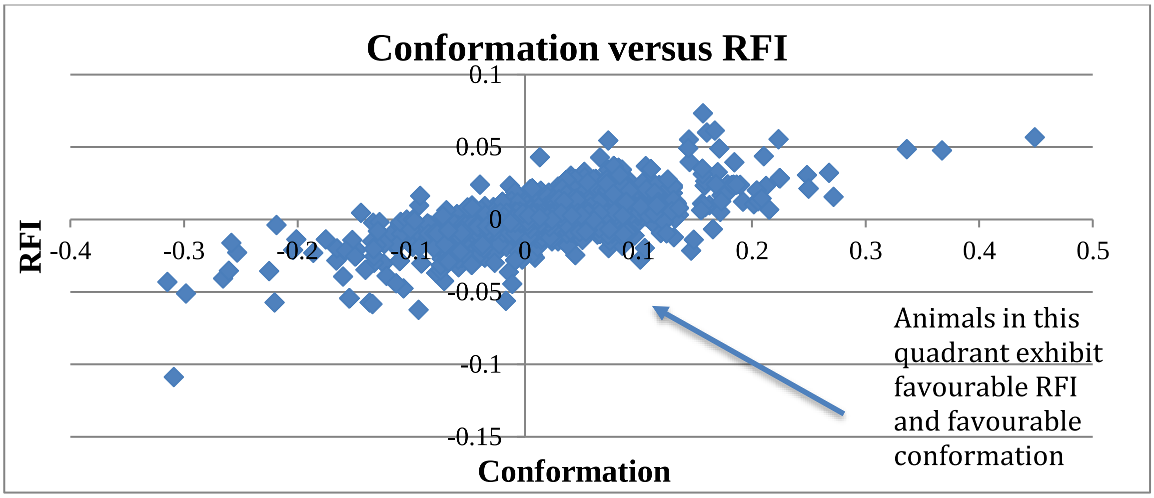

Table 3 shows the potential benefit from selection on alternative combinations and breeding goals and trait recording using results generated in this project. Key results generated to derive this table for UK beef production included:

- trait definition for feed efficiency
- feed efficiency data including recording protocols
- genetic parameter estimates for feed efficiency traits in UK crossbred cattle
- genetic correlations between feed efficiency traits and other beef traits including carcase traits
- derivation of new economic weights for UK terminal beef production indices including the generation of economic weights for carcase traits and feed efficiency traits for the first time.

Combining these data allows modelling of the potential impact of selection within UK beef herds. Including RFI as a trait in the breeding goal and the selection index (i.e., with recording data) showed that the annual economic response per breeding cow increased by £0.85 (£2.10 to £2.95) in comparison to the current industry standard goal/traits. This expected response is cumulative over time. The accuracy of selection increases with the inclusion of more data in the index increasing from 0.56 to 0.67 by adding feed efficiency records and to 0.85 with the additional inclusion of carcase traits data.

Scaling the potential industry impact of widespread and continued recording of feed intake and uptake by the industry we also modelled the benefit across the industry assuming similar penetration rates to those seen currently. The benefits are expressed over 20 year horizon assuming 10 years of continued selection and all benefits are discounted according to UK treasury methodology for economic and GHG benefits. It can be estimated the current breeding goal has a potential approximate value to the industry of £30.9 million. Beginning to include records of RFI in the breeding goal was estimated to increase that economic response by 40% to £43.4 million. Building on previous work it was also shown that the GHG savings were improved by 27% over the same time period – an increase in the rate of reduction compared with using the current breeding goal.

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Table 3: The impact of the “current” breeding programme without and with records on RFI and carcase information for a range of breeding goals when selection intensity is 0.1

	Without RFI records		With RFI records		
	Current Goal	**Current + RFI**	**Current Goal**	**Current + RFI**	**Current + RFI + Carcase**
BWT-direct	0.06	0.08	0.06	0.07	0.05
WT200	1.66	1.74	1.42	1.37	1.08
WT400	3.11	3.34	2.78	2.44	2.16
MSC	0.04	0.05	0.04	0.03	0.03
FD	0.3	0.16	0.05	0.09	0.45
MD	1.76	1.93	1.63	1.35	1.34
CW	1.54	1.55	1.55	1.48	2.67
CFS	0	0	-0.02	-0.01	0
CCS	0.04	0.03	0.04	0.03	0.02
GL-direct	0.02	0.01	0.01	0.01	0.03
CD-direct	0.01	0	0.01	0	0
RFI-growing	-0.79	-3	-5.73	-15.02	-13.47
Annual Economic Response (£/cow)	2.1	2.23	2.65	2.95	3.76
Index Accuracy	0.56	0.5	0.61	0.69	0.85
Industry (Farm Profit)	£30,916,867	£32,830,768	£39,014,142	£43,430,837	£55,355,914
GHG (t CO2e)	-725,621	-749,011	-811,342	-917,998	-1,306,470
Profit (% change from current)	0%	6%	26%	40%	79%
GHG (% change from current)	0%	3%	12%	27%	80%

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4. **Discussion**

This study has made it possible to test protocols and to collect significant quantities of feed intake data on two breeds of cattle. The aim of the project was to collect feed intake data from 1,800 cattle and for the Limousin breed this was surpassed with a total of 1,949 animals. There were 396 sire groups in the analysed dataset (Angus and Limousin).The data has made it possible to test models and to provide preliminary estimates for feed efficiency traits in Limousin male cattle.

It has been demonstrated that feed efficiency traits are heritable and should respond to selection. The analyses produced heritability estimates which were within the expected ranges given in literature from other studies. In this study heritability estimates were moderate in magnitude for RFI, ADG, and DMI ranging from 0.24 to 0.46. Although wide ranging estimates have been given in previous studies the estimates of heritability reported for RFI, ADG, and DMI in general have been moderate (0.2 to 0.5) (as summarised by a meta-analysis that combined results from a range of studies from different countries and breeds). The meta-analysis reported wide ranging estimates across studies for genetic correlations between feed efficiency traits and carcase traits. The mean genetic correlation across studies for RFI with carcase fat, RFI with conformation, and RFI with carcase weight were 0.06 (0.06), -0.30 (0.05), and -0.11 (0.06) respectively, but correlation estimates did vary from negative to positive in individual studies. In the present study genetic correlations between RFI with net carcase weight, fat and conformation were positive, however standard errors were high. Again, it is important to emphasise that this project dealt with crossbred animals including both beef-beef crossbreds and beef-dairy crossbreds. Previously, it has been found that the direction of genetic correlations between some carcase traits differ between dairy breeds and beef breeds therefore we would expect some differences when comparing results to literature using beef breeds only.

Feed is a major cost in all beef production systems and by taking steps to improve feed efficiency will improve margins together with reducing the environmental impact. The potential industry benefits of introducing feed efficiency into routine beef breeding programmes (terminal sires crossed with commercial crossbred suckler cows) was expressed over 20 year horizon assuming 10 years of continued selection. Including records of RFI in the breeding goal is estimated to increase that economic response by 40% to £43.4 million (compared to £30.9 million – a difference of £12.5m) and increase the rate of reduction in GHG savings by 27% over the same time period. It should be noted that sires and semen from terminal beef breeds are also used in the dairy herd and this will lead to additional economic and environmental benefits from the crossbred progeny from those matings. This will be dependent on the focus of “improved” beef semen for use in the dairy herd in terms of which traits take priority in the selection of terminal sires, with a current focus around calving ease.

In practical terms, the figure below demonstrates that that the difference between the top and bottom 10% of the Limousin portion of the dataset, when ranked on RFI, is 1.93kg /hd/day of feed saved. This equates to £0.25/hd/day saving in feed costs, and over a 120-day finishing period would be £30 per hd. On a unit finishing 750 hd per year, the saving would be £22,500, which is a significant sum, given that feed represents 70% of variable costs. If we assume this sample is representative of all prime slaughtered beef cattle in the UK and is scaled up then we would achieve a saving of about £61 M on all cattle finished over a 120 day period

Feed saved can also be expressed as a measure of fodder not made, land not taken up with fodder or grazing production, grain not grown for feed production, or stocking density increased. In this example, there would be an individual reduction of silage required of 151kg/hd or 114T of silage for 750hd, or 7.5 ha/hd of ground not required for fodder production, and across the industry a reduction of 13,000 hectares used for grazing and forage production.

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Figure 3. Top and Bottom 10% of Limousin sire groups, ranked by RFI.

	DDMI (kg)	Age trial start (age)	Growth rate	Weight gain (kg)	Count
Top 10%	7.87	341	1.3	82	194
Bottom 10%	9.80	345	1.3	79	194
Difference	**1.93**	**4.00**	**-0.04**	**-3.00**	

This investigation would benefit from the collection of more data and an improved data structure to confirm the results of this work. If there were to be a continuation of collecting feed intake data then it would be expected that over time the progeny numbers per sire could be further built upon using a targeted approach in obtaining progeny from specific sires. However, at the same time, sourcing the animals at the right age and meeting the other requirements can already be challenging and it is important to use the equipment to their full capacity. As part of this study we did not specify any further protocols for after the trial period such as finishing of the animal and its sale for slaughter. However, fortunately we were able to extract slaughter data for some of the trial animals from data already collected from specific abattoirs. Nevertheless, data on some animals is missing on carcase traits and, although recording of sire is on the increase in British Cattle Movement Service (BCMS), missing information still leads to many animals being dropped from an analysis, particularly on studies in the commercial sector. Further some animals' carcase data is necessarily missing because they have not yet been slaughtered so no data is available.

The trials are costly and whatever can be done to reduce costs without compromising data quality should be considered. Several studies have investigated the length of the data recording period. It would be advantageous to reduce the data recording period length to enable more animals to go through the trials within a given time thus providing more phenotypes and therefore improving the accuracy of genetic parameter estimates and resultant estimated breeding values. However, the current trial length of 63 days was chosen to allow days to be excluded if problems occurred, such as power failures or equipment needing repairs. These extra days were required for some trials. An automatic weighing unit that weighs cattle such as when they are at a water trough could benefit the trial by reducing the staff time for weighing, potentially eliminating human error, and reduce associated stress on the animals, as long as the technology is reliable. An automatic weigh unit would also provide several measurements daily rather than a weekly manually recorded weight. Reducing the number of manual weighings was investigated by removing weights from alternate weeks (i.e. fortnightly weights rather than weekly). This did not affect the accuracy of the data for 'non-problem animals' that grew linearly but it may lead to overlooking animals that appear to grow linearly with half their weights but their weight has actually fluctuated in between. Thus it has been recommended that as long as manual weighing is employed, weighing should remain weekly, rather than reduced to fortnightly. In contrast, the data demonstrated that the initial scanning results were not significantly useful and could be removed from the protocol as long as the age groups studied remained similar. Experience in these trials has also demonstrated that there is no benefit in extending the acclimatisation period past 21 days as any animals that are identified as not acclimatising will be evident prior to the elapse of this time period given the 24/7 monitoring of feed intake data. Further, it has been recommended that sire group sizes should be increased to 6-20 in an effort to stabilise data structure.

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5. Future Work

5.1. Building Industry Commitment

As part of the commitment to building industry engagement, the BFEP has used a knowledge exchange platform to begin to engage with farmers and breed societies, in the form of open industry meetings held on BFEP units. Evidence from farmer meetings conclude that beef finishers are interested in purchasing cattle that can be shown to be sired by a bull of high genetic merit for increased feed efficiency. Being able to transfer this information at the point of sale will be key to increasing demand for more feed efficient store cattle. The British Limousin Cattle Society are actively seeking ways to continue recording feed intake to maintain and increase the accuracy of their newly generated EBV, and also intend to add this trait to their Genomic EBV schedule. A recent circulation to their membership contained the following passage with reference to the Beef Feed Efficiency Programme:

> "Adding feed efficiency traits to the Limousin EBVs currently available further strengthens the opportunity for producers to drive efficiencies within their herds. Through selection of high genetic merit breeding animals, producers will be able to exploit new opportunities to reduce variable costs through reduced feed intake in their animals. Building feed intake traits into a new index will enable suckled calf producers and finishers to find sires that help increase returns through feed efficient, fast finishing calves with best possible carcase quality."

The Limousin breed represented 15% of calf registrations in 2017, second only to Holstein. The BFEP has been able to collect data on enough Limousin-sired cattle to create an estimated breeding value for feed efficiency for Limousin sires. If the uptake of EBV use in selection decisions is 76% (BLCS Bull Buyers survey 2016) then the proportion of cattle that will benefit from having been sired by a more feed efficient sire is over 1 in 10, and the benefit will begin to be realised in 30 months' time. The remainder of the industry will not have this opportunity available unless the programme is extended to enable data collection on further breeds. It will be possible to use the example of Limousin to introduce the remainder of the industry to the concept, and this will be most effective now that tangible tools have been delivered to the industry to enable breeding decisions.

With feed costs likely to show continual increases in the future due to increasing demand for land and increasing costs of other inputs, including rent; the future of the beef industry relies on a strategy that targets reducing input costs, increasing throughput as well as optimising product output. Research in the US has resulted in an estimate of a 1% improvement in feed efficiency having three times the positive economic impact of a 1% increase in live weight gain. More feed efficient animals require less land for grazing or conserved forage provision, resulting in an increase in stocking densities and a reduction in the overall volume of land required for beef production. Further, benefits in selection for feed efficiency in growing animals fed in yards is thought to be transferable to grazing animals, both finishing and suckler cow populations. Thus the sustainable intensification of all beef sectors can be realised through selection of pedigree populations.

5.2. Further research opportunities

While industry clearly needs to develop a sustainable approach to delivering ongoing data collection and calculation of breeding values, DEFRA has confirmed its commitment for additional research to build on the platform, explore a new approach and further catalyse industry engagement.

This will be an opportunity to use this programme as a model for testing use of cross-bred commercial data recording to generate a cross-breed genomic approach for estimating breeding values. This would accelerate genetic progress across both the pedigree and commercial sectors. This has never been done before and the data collected will build a structured cross-breed data set to enable research in this area.

There is also poor understanding of the biological mechanisms that underlie differences in feed efficiency between animals. This extension work will explore whether selection for feed efficiency has an effect on meat quality. A small number of loin samples have already been collected and it is expected that 1500 additional loin samples will be collected as part of the extension work.

An important aim of any proposed follow-on work in this area would be to build on the existing work towards a situation where the value to industry drives uptake of the technology, and the cost of ongoing recording can be justified by the increased profitability delivered. Further work would deliver in this two main ways:

1. Reducing the cost of delivering EBVs through:
    a. Novel genomic approaches (across breed - built into underlying platform)
    b. Identification of alternative, lower cost, phenotypes to reduce recording cost (option 3)
2. Adding value by:
    a. Ensuring selection for feed efficiency does not compromise quality, and paving the way to incorporation of eating quality parameters in genetic evaluations

The establishment of a sustainable business model has proved difficult following the first phase of the programme, but the delivery of tangible benefits (publication of EBVs) at the end of the first phase, and further building on these with follow-on work, will help build confidence to establish the ongoing industry-led programme. Alongside further technical developments, we need to demonstrate tangible ways to translate findings and results to the industry. AHDB is working, alongside the Livestock Information Programme on the possibility of implementing a system that easily enables store cattle producers to identify potential purchases that are genetically of higher merit. This could incorporate feed efficiency providing a direct route to delivering information on the genetics of feed efficiency to commercial producers