INTERNATIONAL FARM MANAGEMENT CONGRESS 2003
FARMING AT THE EDGE

UPTAKE OF SEXED SEMEN BY UK SUCKLER BEEF PRODUCERS

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ABSTRACT

Dairy farmers have been able to use sexed semen from dairy breeds to pre-determine the sex of calves since 2000, sexed semen from beef bulls is not currently commercially available, but is expected within 2 years. A survey of a stratified random sample of suckler cow farmers is used to identify the potential uptake of sexed semen when it becomes available using a logistic limited dependent variable model to identify different characteristics between farmers who intend to use sexed semen and those who do not. Herd size, the perception of the quality of bulls used to produce sexed semen, anticipated problems using AI, concern over conception rates, the cost and profitability of using sexed semen and herd replacement policy are found to be the major factors that will influence uptake. The relative importance of each constraint is shown, and approaches to reduce these constraints discussed.

INTRODUCTION

Suckler beef farmers produce calves for sale as suckled calves, store cattle and for taking on as finished animals for slaughter, and for breeding. Depending upon the role envisioned, males and females are of quite different value. This is the reason why pre-selection of sex is the most important development in reproductive technology since the introduction of commercial artificial insemination (AI) (Seidel, 2003). Sex affects both biological and economic efficiency (Hohenboken, 1999). As males have higher carcass weights and better feed conversion during fattening, more meat is produced per unit of feed and other input items. This results in the use of less energy and less production of manure thus enhancing the sustainability of beef production. However, heifer calves may be required from certain cows in order to provide the best herd replacements. These factors mean that the ability to sex semen is potentially a powerful technology.

Several different techniques for sexing semen have been proposed, but to date the only technique that has been used in a practical sense is a procedure that measures the DNA content of individual sperm via fluorescence of the DNA-binding dye (Seidel, 2003) while sperm are processed through a flow cytometer/cell sorter. Bovine X-chromosome bearing sperm have 3.8% more DNA than Y-chromosome bearing sperm which enables sexing to take place (Seidel, 2003;

Amann, 1999; Johnson, 2000). The purity of the sorting depends on the sort speed - an inherent problem is having to evaluate sperm one at a time. Sorting speeds also depend on the characteristics of the individual ejaculate and on the species. Typically the sort speed for a bull is in the range of 6000-8000 live sperm per second at 90% accuracy (Seidel 2003; Cran, 2000). Net sperm production is about 11 million live sperm of each sex per hour, or approximately the number of live sperm in one dose of conventionally processed frozen semen. A typical insemination dose using sexed semen currently uses around 2 million sexed, frozen sperm. Sperm sexing removes dead sperm but also damages some sperm. With good management, fertility with low doses of sexed sperm has been around 70-80% of normal doses of unsexed sperm (Seidel et al., 1999). Sorting speed is the primary limitation of this technology (Seidel, 2003).

The first reports of the birth of offspring (rabbits) resulting from insemination with flow cytometrically sorted sperm was published over ten years ago (Johnson *et al*. 1989). The first heifers borne in the UK using fresh sexed semen occurred in 1999; at Cogent's Aldford farm (Falkingham, 1999). After large-scale trials involving around 300 cows (mostly heifers) from about 40 farms investigating the use of fresh and frozen sexed semen, different dosage rates and different deposition sites in the uterus (McEvoy, 2000), sexed semen became commercially available from dairy breeds in 2000. When sexed semen was first produced and marketed (by the UK firm Cogent) it cost either £29 or £35 per straw and purchase was tied to the purchase of five non-sexed straws. Sexed semen can now be purchased without unsexed semen. The lower profitability of suckler cow compared with dairy enterprises, and the lower incidence of AI use on suckler herds, has meant that sexing dairy breeds has been prioritised, but semen from beef breeds is now being sexed and trialled on farms.

The structure of the paper is as follows. The next section introduces recent trends in the structure of suckler herds in the UK. This is followed by a brief examination of the theoretical determinants for using sexed semen, followed by an introduction to the data used in the analysis. The logit model is then introduced and used to identify the factors that identify the characteristics of farmers who intend to use sexed semen. The final sections examine some policy issues and concludes the paper.

THE STRUCTURE OF BEEF PRODUCTION IN THE UK

UK-produced finished beef originates from calves born from dairy and suckler herds. In several respects, the dairy and suckler beef herds are interdependent. It is the total volume of marketed beef that affects market prices. Direct subsidy payments for bull beef, beef special premium payments and suckler cow payments are dependent on the total number of claims in the UK (through the national ceiling and the clawback mechanism).

An additional interdependence is the traditional use in suckler beef herds of crossbred beef heifers from dairy herds as suckler cow replacements. However, the annual decline of the UK dairy herd of about 51,000 cows/year has meant that this source of suckler cow replacements has declined in recent years. The quality of replacements has also fallen with Holstein Friesians gradually replacing the traditional British Friesian cow (Alston, 2000). The Holstein is an efficient converter of forage into milk, but produces calves that are less suitable as suckler cow replacements than the Friesian.

THEORETICAL DETERMINANTS OF USING SEXED SEMEN

The uptake of a new technology will be dependent on the characteristics of the technology and the attitudes of those who would use the technology. Rogers (1995) suggests the characteristics of an innovation which may affect its rate of adoption: relative advantage (e.g. economic, comfort, time and effort); compatibility with existing practices, values and beliefs; complexity (a negative relationship); trialability (the opportunity to test the technology before adoption or during a phased introduction); and observability (producing visible evidence of advantage).

A key characteristic of sexed semen is that farmers must master AI in order to use it. So uptake of sexed semen will most readily occur in those sectors of the livestock industry and on those farms which already use AI, with sectors that could adopt AI next in line (McEvoy, 2000). Farmer's attitudes to reproductive strategy will also be important. Many suckler beef producers prefer to use a bull rather than use AI. They may lack the expertise to diagnose oestrus, they may not like the AI bulls available, it may be cheaper to use a bull, for example if a home reared replacement was used. There is always some risk involved with using a new technology, so each farmer’s risk aversion will influence whether and when a new technology is used in the production process. It is likely that a proportion of suckler beef farmers will have ethical objections to the use of sexed semen. The ability to adapt management systems to utilise sexed semen will depend on the breeding system, housing and handling facilities and labour skills and availability (i.e. farm characteristics). It is likely that a proportion of herds will not be able to adapt to use sexed semen, e.g. extensive grazing, hill farms where animals over-winter outside (Hohenboken, 1999).

The availability of replacement heifers, and herd replacement policy are likely to be key features that determine the use of sexed semen. With the general quality of replacement breeding stock decreasing, suckler beef producers are increasingly producing their own replacements. By using sexed semen, breeders can increase the proportion of replacements from the best cows from their own herd.

The ability for each herd to produce calves of the same sex allows farmers to specialise producing all female replacements, or breeding bulls or males for slaughter. This may result in further specialisation between farmers which will cause far reaching changes to the interactions between the dairy and suckler beef herds, to the structure of beef production and the market for and marketing of beef.

Clearly the economics of using a new technology is an important determinant of the use of that technology. There are several key criteria that will determine the relative profitability of using sexed semen. Amann (1999) draws attention to three: the unit cost of sexed sperm, expected conception rate and purity of semen used. These factors will be influenced by the development of faster and more accurate flow cytometers. Increasing the dose of sperm per insemination would likely increase conception rates but also increase costs. In addition to these, other factors that may influence the uptake of sexed semen are the relative value of male and female calves or finished animals, the management of feeding and marketing, and the importance of the ease of calving in the system being considered.

In addition to these factors, it is possible that there will be a reluctance by the public to purchase products produced using this technology, especially given the current circumstances that surround GMOs.

SURVEY DETAILS

A stratified random sample of suckler beef farms was obtained with strata determined by herd size category, (0 to 30, 30 to 70 and above 70 cows), region (England, Northern Ireland, Scotland and Wales) and Less Favoured Area (LFA) status (inside or outside). In order to generate details on the use of sexed semen, it was necessary to over-sample larger herds. Over sampling is necessary because of the structure of the UK suckler herd, which is shown in Table 1. This shows that a large proportion of suckler cows are concentrated in a small number of large herds; only 15.6% of herds have more than 50 cows but these herds account for 52.4% of the UK beef breeding herd.

A total of 1905 questionnaires were sent out with 520 replies received, a response rate of 27%. A number of responses had to be discarded because of incomplete returns, allowing information from 483 herds to be presented. The distribution of respondents by herd size is shown in Table 1, together with the number of cows in each herd size. Further details of the survey can be found in Telford *et al*, (2003)

Table 1. The Distribution Of Uk And Respondents' Suckler Cows And Suckler Herds By Herd Size; June 2000

	SUCKLER COWS			SUCKLER HERDS		
HERD SIZE	UK COWS	% OF UK COWS	COWS IN RESPONDENTS HERDS	UK HERDS	% OF UK HERDS	RESPONDENT HERDS
1<10	112,373	6.1	170	24,182	36.8	33
10<30	405,101	22.1	1,446	22,124	33.7	74
30<50	353,449	19.3	3,263	9,159	13.9	83
50<100	503,352	27.5	11,588	7,313	11.1	161
>100	456,353	24.9	23,671	2,952	4.5	132
Total	1,830,628		40,138	65,730		483

SOURCE: DEPARTMENT OF AGRICULTURE AND RURAL DEVELOPMENT NORTHERN IRELAND (DARDNI), (2001); DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (DEFRA), (2001); SCOTTISH EXECUTIVE ENVIRONMENT AND RURAL AFFAIRS DEPARTMENT (SEERAD), (2001).

Table 2 shows some summary statistics for the sample of respondents.

Table 2. Summary statistics of respondents

	Average	%
Average farm size (ha)	168	-
Average herd size (cows)	83.1	-
Intend to use sexed semen	171	35
LFA status: inside a severely disadvantaged area	154	32
LFA status: inside a disadvantaged area	113	23
LFA status: outside a LFA	216	45
Use AI in a normal year on a proportion of suckler cows	120	24
Mainly spring or summer calving	277	57
Mainly autumn or winter calving	30	6
Split calving (< 60% in any one season)	175	37

N = 483

LOGIT MODEL

The adoption behavioural model with dichotomous (binary) dependent variables can be used as a conceptual framework to examine variables associated with the adoption of technologies such as sexed semen. The following adoption behavioural model was used to examine factors influencing sexed semen uptake:

$$Y_i = G(Z_i) \quad (1)$$

$$Z_i = b_o + \Sigma\ (j=1 \text{ to } n)\ b_i X_{ji} \quad (2)$$

Where Y_i is the observed intention to use sexed semen (i.e. a binary variable with $Y_i=1$ for a farmers who will use sexed semen (adopters) and $Y_i = 0$ for those who said they would not use sexed semen (non-adopters)).

Z_i is the underlying and unobserved stimulus index for the ith observation (conceptually there is a critical threshold (Z^*_i) for each farmer, if $Z_i<Z^*_i$ the farmers is predicted to be a non-adopter).
G is the functional form chosen to relate the farmer's intentions towards using sexed semen and the stimulus index that determines the probability of using sexed semen.
i = 1, 2, 3, …., m, are the number of observations in the sample.
X_{ji} is the jth explanatory variable for the ith observation, j = 1, 2, 3, …, n.
b_j is an unknown parameter that is estimated in the model, j = 1, 2, … n.
b_0 is a constant.
J = 1, 2, …, n, where n is the total number of explanatory variables.

The logit model assumes that the underlying stimulus index (Z_i) is a random variable which predicts the probability of using sexed semen.
Probability (event) $P_i = e^{Zi} / (1+e^{Zi})$ (3)
Or equivalently:
Probability (event) $P_i = 1 /(1+e^{-Zi})$ (4)
Therefore, for the ith observation (an individual farmer), the stimulus index is a linear combination:
$Z_i = \ln [P_i (1-P_i)] = b_o + b_1X_{1i} + b_2X_{2i} ....b_jX_{ji}$ (5)
The probability of the event not occurring is estimated as:
Probability (no event) = 1 - Probability (event) (6)

483 observations were analysed in the model. Table 3 shows the important predictors that were selected on the basis of a maximum likelihood function using the Backward Stepwise method. The coefficients indicate the effect of the variable on the probability of the observation using sexed semen. The chi-square goodness-of-fit statistic of 170.798 in Table 3 shows the model fits the data with a significance of $p < 0.005$, indicating a good overall fit.

Table 3. Logit model showing the determinates of the use of sexed semen

Variable	Coefficient	Significance
Constant	0.239	0.511
Herd size	0.014	0.002
Does not use AI because believes bulls are inferior	-1.632	0.012

Problems with AI means will not use SS	-7.55	<0.000
Believes cost of SS will to too high	-4.105	<0.000
Does not believe SS will be profitable to use	-4.391	<0.000
Believes SS will deliver a poor conception rate	-5.027	<0.000
Intends to increase proportion of replacements that are home bred	1.53	0.004
About half of current herd is from dairy stock and half from suckler stock	1.081	0.071
% of heifers currently retained for breeding	1.799	0.027
N=483		
- 2 log likelihood	170.798	
Cox and Shell R square	0.612	
Nagelkerke R square	0.841	
Omnibus test of model coefficients	457.015	

IMPACT OF EXPLANATORY VARIABLES ON SEXED SEMEN UPTAKE

The uptake of sexed semen appears to be significantly influenced by herd size, farmers with larger herds are more likely to use sexed semen. Farmers who intend to increase the proportion of home bred replacements and those who already keep a high proportion of home bred replacements are more likely to use sexed semen.

Factors that will restrict uptake include problems using AI. Farmers who believe that the bulls from which sexed semen will be taken are inferior to their own bull, and those who anticipate problems using AI will be less likely to use sexed semen. Farmers concerned that sexed semen will lower conception rates are less likely to use this product. The economics of using sexed semen are an important determinant of likely uptake. Farmers who believe that sexed semen will be too expensive and those who do not think its use will increase profitability are not likely to use sexed semen.

The logit model quantifies the impact of variables for different farming systems. For example, equation 7 shows the impact of an explanatory variable (Table 3) on the mean stimulus index for a farmer with 60 cows, who does not believe AI bulls are inferior, who does not anticipate problems with AI, who does not believe sexed semen will be too expensive but who nevertheless does not believe it will be profitable to use, does not anticipate lower conception rates, who intends to increase the proportion of home bred replacements on the next 3 years and has 50% of their current herd comprised of dairy stock and currently retains 20% of heifers for breeding, and is computed as:

$$I_I = 0.239 + 0.014(60) - 1.632(0) - 7.550(0) - 4.105(0) - 4.391(1) - 5.027(0) + 1.530(1) + 1.081(1) + 1.799(0.2) = -0.3412 \quad (7)$$

The probability of such a farmer (Model A in Graph 1) using sexed semen is therefore,

$$P_i = e^{-0.34} / (1+e^{-0.34}) = 0.41$$

or nearly 41 per cent. This compares to a value of 13 per cent if the same farmer had decided not to increase the proportion of home bred replacements (represented as model B in Graph 1). The estimated probabilities for individual observations are computed in a similar manner and compared with their surveyed response, Table 4 shows that about 94 per cent of farmers were correctly predicted by the model based on a Z^*_i of 0.5.

Graph 1 shows the impact of differences in herd size on the probability of this farmer using sexed semen (model A and model B). As herd size increases the probability of using sexed semen increases. It can be seen that the probability of the farmer who intends to increase the proportion of home replacements using sexed semen (model A) is higher that of the farmer with no such intentions (model B).

Graph 1. Impact of herd size on the probability of using Sexed Semen.

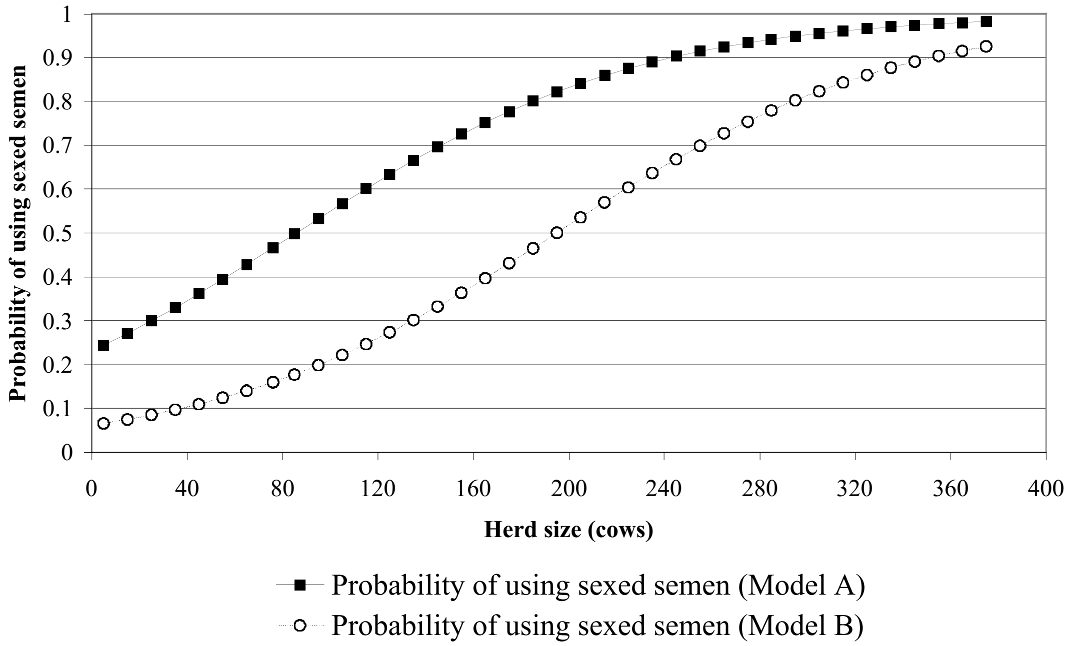

Table 4. Within sample classification accuracy

Observed	Predicted		Total	Correct
	Will not use sexed semen	Will use sexed semen		%
Will not use sexed semen	288	24	312	92
Will use sexed semen	5	166	171	97
Overall totals	293	190	483	94
A nieve prediction of all observations not using sexed semen would give a 65% success rate				

Table 5. Predicted change in the numbers of herds using sex semen with changes in farm management policy and outlook.

Herd size (cows)	No. of farmers	Predicted Original Sample	AI bulls not inferior	No AI problems	SS affordable	SS use will be profitable	No worries about conception rates	Increase use of home replacements
< 30	118	41	54	73	58	58	55	54
30 < 65	125	44	48	72	52	51	50	48
65 < 99	108	38	41	57	43	45	45	41
100 and above	132	48	52	81	54	56	57	52
TOTAL	483	171	195	283	207	210	207	195
% increase			14	65	21	17	21	14

Table 6. Estimates of the number of cows served with sexed semen with changes in farm management policy and outlook.

Herd size	No. of cows	Predicted Original Sample	AI bulls not inferior	No AI problems	SS affordable	SS use will be profitable	No worries about conception rates	Increase use of home replacements
(cows)								
< 30	1946	599	633	743	645	662	638	633
30 < 65	5909	1225	1260	1510	1295	1288	1276	1260
65 < 99	8612	1171	1195	1363	1214	1243	1237	1195
100 and above	23671	4034	4144	5083	4143	4195	4147	4130
TOTAL	40,138	7,029	7,232	8,699	7,297	7,389	7,397	7,218
% increase			2.9	23.8	3.8	5.1	5.2	2.7

* of which, 4,915 to be served with male sexed semen, and 2,114 with female sexed semen

IMPACT OF CHANGES IN ATTITUDE ON SEXED SEMEN USE

The model was used to predict the changes in the probability of sexed semen being used by each farmer. Table 5 shows the predicted estimates resulting from a change in attitude towards the potential problems envisaged in using sexed semen, and herd replacement policy. Originally, 171 farmers had expressed the view they would use sexed semen. If each farmer held favourable views about the bulls that are likely to be used to produce sexed semen, this number would increase to 195 (14%). A 65% increase in use (to 283 farms) would result if farmers were able to overcome the envisaged problems of using AI, a necessary precursor to using sexed semen. Numbers of sexed semen users would increase by 36 (21%) if concern about conception rates was eliminated, and by a similar number if sexed semen was marketed at an "affordable" price. A change in herd replacement policy to increase use of home bred replacements would result in 24 (14%) more farmers using sexed semen.

Graph 1 shows the impact of herd size on the probability of a using sexed semen. Model B differs from model A only in that the farmer does not intend to increase the proportion of home bred replacements (see above). At every herd size the farmers represented by model A is more likely to use sexed semen but for both sets of attitudes, as herd size increases so does the likelihood that sexed semen will be used.

The impact of these constraints on the total demand for sexed semen can be calculated from the herd size of the farmers in each herd size band. The total number of cattle that would be served with sexed semen within the herds surveyed was 7,029 (17.5%). The number served after each individual constraint on the use of sexed semen was removed is shown in Table 6. For example, if AI were no longer to be considered a problem, it is estimated that an additional 23.8% of cows would be served with sexed semen. These estimates assume that farmers who would change their intentions would serve the same proportion of their herd with sexed semen as farmers in the same size category.

CONCLUSION

The main factors that will influence the use of sexed semen are herd size, the ability to use AI and its financial viability. There is likely to be difficulty using AI on some UK suckler cow herds, particularly perhaps extensive herds which calf in the spring and would be outside during the service period. If sexed semen is used, these systems will incur high labour costs thus reducing the viability of using sexed semen (Doyle, 2000; Seidel, 2003).

Farmers will need clear estimates and assurances of the profitability of sexed semen. Direct payments account for about 40% of the value of beef finishing enterprises. Currently, farmers are entitled to receive direct payments for beef animals, but these vary with the sex and age of the animal. The direct payment budget is constrained by a clawback mechanism, which applies once national claims exceed the national ceiling. Sexed semen will alter the proportion of male to female animals produced. Furthermore, with prices likely to change also, it is likely that the proportion of male animals will increase. These changes could potentially cause clawback of Beef Special Premium Payments, thereby lowering the value of each claim made on steers and bulls. The value of using sexed semen will therefore be determined by its uptake and use by farmers within national ceiling areas, increasing the difficulty of calculating the value of using sexed semen on individual farms.

The unit price of sexed semen will be a key determinant of its uptake, and therefore the pricing policy of the suppliers of sexed semen is likely to be an important factor in establishing total useage. Supply is limited to one company at present, allowing it to price discriminate should it wish to, which would increase usage. Should the suppliers of sexed semen acquire farm enterprise costings data, then it could, in principle, increase market demand by price discrimination.

Recent improvements in sorting procedures have reduced the damage caused to sperm (Seidel, 2003), which, together with improvements to cryopreservation, have decreased the unit cost of producing a dose of sexed semen and raised its fertility (Seidel 2003). These technological advances may result in lower prices to farmers.

The reduction in quality dairy bred replacements has resulted in a higher proportion of replacements being acquired from suckler herds, often as home bred replacements, and sexed semen could accelerate this trend. But suckler cow farmers have more diverse breeding objectives than dairying farmers, and the survey found that the selection of the appropriate bull from which to sex semen is a major concern of farmers. As the use of sexed semen relies on the ability to use AI, so it itself may well encourage the wider spread use of breeding technologies and encourage specialised, high value breeding programmes. Sexed semen may facilitate the use of multiple ovulation and embryo transfer techniques. If one of the main advantages is the high value in producing heifers using female semen, then sexed semen would ensure that a large proportion of transferred embryos give heifer calves, thereby increasing the value of the procedure. There could also be some use of sexed semen to produce breeding bulls in advanced breeding programmes.

The availability of sexed semen has the potential to change the structure of suckler beef production and alter the structure of the marketing chain. Possible innovative production systems include using sexed semen to produce a female heifer calf which is kept as a replacement allowing its dam to be slaughtered. This system would increase the biological efficiency of beef production. Other farmers might specialise in producing replacement heifers, others in producing steers for stores and fattening, buying in all replacements.

With respect to marketing arrangements, using sexed semen should give a more uniform product. More similar genetics, raising calves batched by sex would simplify feeding routines and simplify management systems. Less Holstein genetics in the final product should increase carcase quality and raise the proportion of high value meat. Specialisation between producers and moving towards a more uniform product should shorten the marketing chain, increase relative market power of farmers, and reduce wastage caused by non-uniform stock and irregular supply of beef onto the market. Sexed semen therefore, has the potential of changing production systems on a global and a local scale.

BIOGRAPHICAL DETAILS

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the award of a postgraduate scholarship from the Meat and Livestock Commission which has enabled this work to be completed. Further thanks are also extended to Sheila Magee from DARDNI, the staff at DEFRA, Venetia Radmore from SEERAD and Bill Harper and Lesley Lewin from the National Beef Association (NBA) South-West Regional Council, the NBA, the National Farmers Union (England), and the National Farmers Union of Scotland for supporting the survey, and Penri James from the Welsh Institute of Rural Studies for kindly translating the questionnaire into Welsh. Finally, the authors would like to thank all the respondents who completed the questionnaire. Without their co-operation, this research could not have been conducted.

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