Journal of Dairy Research (2013) **80** 45–50. © *Proprietors of Journal of Dairy Research 2012*
doi:10.1017/S002202991200060X

Predisposing factors for involuntary culling in Holstein–Friesian dairy cows

Daniel Chiumia[1], Mizeck G.G. Chagunda[1]*, Alastair I. Macrae[2] and David J. Roberts[1]

[1] Scotland's Rural College (SRUC), West Mains Road, Kings Building, Edinburgh, EH9 3JG, Scotland
[2] Royal (Dick) School of Veterinary Studies and The Roslin Institute, Easter Bush, Midlothian, EH25 9RG, Scotland

Received 21 December 2011; accepted for publication 9 July 2012; first published online 20 November 2012

The objective was to identify predisposing factors for increased risk of involuntary culling in adult Holstein–Friesian dairy cows. Data were sourced from Scotland's Rural College (SRUC) Dairy Research Centre. Between September 2003 and August 2010 175 cows were culled, a herd culling rate of 33·7%. The major reasons for involuntary culling were fertility (27·4%) and udder problems (26·9%). In the analysis, the culled cows were matched with their cohorts that survived to a later lactation. To identify predisposing factors, a binary logistic model was applied. Cows with higher than average body condition score (BCS) at last service were five times [Odds Ratio (OR) = 4·8] more likely to be culled due to infertility. Cows with low protein yield on day 60 ± 5 in lactation were ten times less likely (OR = 0·1) to be culled. In first lactation heifers, only BCS at last service increased the risk of involuntary culling due to infertility (OR = 13·0). A high milk yield acceleration was a significant (P = 0·04) factor in increasing the risk, five times (OR = 5·2) more, of culling cows due to udder problems. In conclusion, a high BCS at last service, high milk protein yield at around day 60 in lactation and acceleration of milk yield after calving exposed cows to a risk of being culled involuntarily. In practice, monitoring of traits that indicate metabolic imbalance could assist identifying cows at high risk of being culled and contribute to reducing the associated risk through a more effective timely decision.

Keywords: Fertility, udder health, negative energy balance, body condition score.

To optimize dairy production it is extremely important to understand the culling process in dairy herds and its consequences (Hadley et al. 2006). Involuntary culling is when a cow leaves the herd for reasons that are not of the farmer's choice. Unlike voluntary culling where a farmer chooses to sell a cow to obtain the cow's beef value, involuntary culling occurs without conscious control or direction from the farmer. On the one hand, culling voluntarily due to age, low milk production and/or to maintain a herd size aims at maximizing returns. On the other hand involuntary culling is a cost to the farmer. One of the factors attributed to involuntary culling is the deterioration of fertility in dairy cows which is a negative correlated response to selection for higher milk (Lãvendahl & Chagunda, 2006). Indicators of reduced reproductive performance such as a lower conception rate which increases involuntary culling rates are also evident (Waiblinger et al. 2004; Wathes et al. 2007; Cozler et al. 2009). The major reported reasons for culling in dairy herds include fertility, lameness and udder health (Bascom & Young, 1998; Cozler et al. 2009; Orpin & Esslemont, 2010). Fertility challenges are associated with both the genetic value for milk production of the cows (Mulligan et al. 2007; Wathes et al. 2007; Knop & Cernescu, 2009) and metabolic disorders (Gillund et al. 2001) while lameness incidences are mostly linked with housing condition (Rushen & de Passille, 2006). Since the introduction of machine milking, udder health in dairy cows has also generally deteriorated (Hovinen & Pyörälä, 2010). Assisted calving, abortion and mastitis are also some of the risk factors associated with culling (Bell et al. 2010). However, examining the factors behind the specific reasons of culling in dairy herds would be a useful way to better understand the processes and consequences and hence help to derive more effective solutions than not (Hadley et al. 2006). This could be aided by identifying practical indicator traits that could be used to

*For correspondence; e-mail: Mizeck.Chagunda@sruc.ac.uk

identify cows at an increased risk of being culled. The present study was conducted to determine factors that increased the vulnerability of dairy cows to involuntary culling before finishing their reproductive and productive life in different dairy systems. Specifically, the objective was to quantify factors resulting in an increased risk of involuntary culling in a Holstein–Friesian dairy herd with particular focus on metabolic imbalance.

Materials and Methods

Data

Data used in the present study were for cows which had calved between September 2003 and August 2010 sourced from the Scotland's Rural College (SRUC) database for the Langhill herd. The animals were part of the long-term 2 × 2 factorial, genotype × feeding regime Holstein–Friesian dairy cow research herd described earlier (Bell & Roberts, 2006). The two feeding systems were high forage system (HF) and low forage (LF). In the HF system, the cows grazed when sufficient herbage was available and were fed a complete diet containing 70–75% forage in the dry matter (DM) when grass heights fell below set values and in the winter months. In the LF system, the cows were housed throughout the year and were fed a complete diet containing 45–50% forage in the DM. Each feeding system consisted of cows that belonged to one of the two genetic lines (Select and Control) based on merit for kilograms milk fat plus protein (Chagunda et al. 2009). Control line had cows with average UK genetic merit for fat plus protein while Select cows were the top 5% of UK genetics based on fat and protein. Thus the study had four production systems: high forage control (HFC), high forage select (HFS), low forage control (LFC) and low forage select (LFS). All cows on the high-forage diet were at grass during the summer whilst cows on the low-forage diet were housed in free stalls throughout the year. One total mixed ration was used for each group throughout the lactation. Cows were milked three times a day and assessed for body condition weekly. Body condition scoring was performed by two persons and was based on a 5-point scale over the period of the study in alternation. The same individuals were involved in body condition scoring of the cows over the 7-year period. These were experienced permanent employees trained to body condition score as part of routine management practice. For quality assurance reasons, staff alternated weekly to avoid individual bias.

To identify the main reasons for involuntary culling in the herd, cows were classified depending on the herd recorded reasons for culling. All animals that were culled because they were not seen on heat, repeat breeders and all those that had reproductive disorders were classified as being culled due to infertility. Cows with lost quarters, mastitis, high somatic cell counts (SCC) (equal to or greater than 400 000 cells/ml), damaged udder and poor udder conformation were classified as udder problems. Cows that were culled because of sole ulcers, digital dermatitis, heel erosion and leg fracture were classified as cows with foot or leg problems. Cows that were culled due to accidental injury and deaths were identified as a separate group. There were also cows that were recorded as being culled due to either unknown or other reasons. These were classified as such. Based on the total number of cows culled per reason, infertility and udder problems were the major reasons for involuntary culling in the Langhill dairy cow herd.

Variables evaluated

Variables in each of the three models fitted were prior assessed for correlation to prevent multicolinearity. Mean daily milk yield within the lactation in which the cow was culled, age at first calving, metabolic calving weight (calculated as pre-calving body weight$^{0·75}$), calving ease, body condition score (BCS) at calving (week of calving), BCS at last service, genetic line, feeding system, mastitis incidence, milk protein yield at day 60(± 5), calving season and calving year were variables assessed for increased risk of involuntary culling cows due to infertility. A cow with a normal calving had a response variable 0 and 1 for cows with abnormal calving. Mastitis was a class variable, with value 1 if diagnosed with mastitis and value 0 if not in the lactation of the culled animal. BCS at last service used in the analysis was the score recorded at successful service or the last service if the cow was culled before confirmed to be in-calf. Code 1 of the UK season was for spring and 2, 3 and 4 for summer, autumn and winter, respectively. Calving year had values from 1–8 for 2003–2010. A further binary logistic regression analysis was conducted on first lactation heifers culled due to fertility reasons because infertility was the predominant reason for involuntary culling first lactation heifers.

Variables evaluated for an increased risk of involuntary culling cows due to udder problems were: duration of milking per milking time in a day, peak milk flow rate (recorded by the machine), parity number, diseases and milk yield acceleration (calculated as change in milk yield over change in days in milk). Milk yield acceleration is a way of combining milk yield and days from calving. This crystallizes the components of these two factors into an index that is designed to reflect the physiological stress being experienced by the cow (Ingvartsen et al. 2003; Chagunda et al. 2006). The rate at which a cow performs, either in absolute terms or relative to a potential maximum, is generally agreed to be an important factor in determining that animal's ability to cope with metabolic load (Kronfeld, 1976; Knight et al. 1999). The majority of stress-induced diseases occur substantially earlier than the peak of milk production. As such Ingvartsen et al. (2003) argued that milk yield acceleration, whose maximum occurs just after calving, may be a better indicator of physiological stress. Milk yield acceleration is the first derivative of daily milk yield (l/d); hence, the units for milk yield acceleration are l/d per d. Milk yield acceleration was calculated based on first recorded

https://doi.org/10.1017/S002202991200060X Published online by Cambridge University Press

Table 1. Summary of number of cows culled per reason in a Holstein–Friesian dairy herd over a 7-year period

Reason for culling	Cows, *n*	Cows,% rate	First parity cows, *n*	First parity cows% rate
Infertility	48	27·4	23	41·1
Udder problems	47	26·9	13	23·2
Accidents	32	18·3	11	19·6
Unknown	20	11·4	5	8·9
Foot or leg problems	22	12·6	2	3·6
Died	6	3·4	2	3·6
Total	175	100	56	100

Table 2. Descriptive statistics of some of the variables in fitted binary logistic models of predicting the risk of culling in a Holstein–Friesian dairy herd

	Mean (SD)		
Variable	Culled	Control	Animals per group
Age at first calving, months	26·1 (3·0)	25·9 (2·5)	33
Metabolic calving weight, kg	119·5 (12·0)	119·6 (12·0)	33
Body condition score at last service*	2·2 (0·4)	2·0 (0·3)	33
Milk protein yield at day 60 ± 5, kg*	1·2 (0·3)	1·3 (0·2)	33
Milk yield acceleration, l/d per d*	0·7 (0·6)	0·5 (0·3)	34
Peak milk flow rate, l/min	4·0 (1·5)	4·2 (1·1)	34
Duration of milking, min	9·8 (3·6)	9·7 (2·7)	34

*Significantly different ($P<0·05$)

milk yield after calving and peak milk yield for each individual cow.

Class variable diseases had variable 1 if the cow had a history of being diagnosed with any of the following in the lactation of the culled cow: teat blockage and contusion, hard quarters, teat injury, retained placenta, ketosis and milk fever and variable 0 if not.

Statistical analysis

In the analysis, culled cows were matched with their cohorts that survived in the same lactation in which the cow was culled. Further matching was based on age at first calving, feeding system and genetic line. Differences in mean values of variables between culled and control cows were analysed using ANOVA. To quantify predisposing factors, a backward stepwise multiple regression binary logistic model was applied. Both CATMOD procedure and logistic procedure were used. All the analyses were conducted using Statistical Analysis Systems (SAS) version 9.2 (SAS, 2008). The dependent variable, the fate of being culled, was a discrete variable with only two outcomes. The value 1 represented cows that were not culled and 0 otherwise. Fit models were isolated based on likelihood ratio goodness-of-fit test in the CATMOD procedure output. The process of fitting the models involved manually removing variables from each model starting with variables that were not significant until the likelihood ratio indicated goodness-of-fit for the model at 5% confidence level. The model automatically excluded all the records with missing values in one of the variables. This resulted in only cows with complete records being included in the analysis.

Results

Reasons for involuntary culling

During a 7-year period, 175 animals were culled for various reasons, representing a 33·7% herd culling rate. The predominant reasons for involuntary culling were infertility (27·4%) and udder problems (26·9%) (Table 1).

The involuntary culling rate in first lactation heifers was at 32% with more cows (23) culled due to fertility reasons than the rest of the reasons individually. Within all cows culled due to infertility, 87·5% were repeat breeders, 10·4% had reproductive disorders and 2·1% were not seen in heat. For cows culled due to udder problems, 53% were culled due to mastitis, 17% poor udder conformation, 15% lost quarter, 11% high SCC and 5% damaged udder.

The highest involuntary culling rate by production system was recorded for select line cows on low-forage diet regardless of parity. The overall culling rate was 33·1 and 10·3% in first parity cows. The overall culling rates for LFC, HFS and HFC production systems were 27·4, 21·1 and 18·3%, respectively. In first parity cows LFC and HFS systems had both 6·9% culling rate which was lower than in HFC system (8·0%).

Predisposing factors

The variations in means between the culled and control cows for the variables BCS at last service, milk protein yield at around day 60 and milk yield acceleration were significantly different ($P<0·05$). The rest of the variables were not statistically different. Table 2 details the average values of variables included in the final fitted models except those with numerical codes such as mastitis and calving season.

Culls included in the analysis had a daily average milk yield of 27. 6 l (SD = 6·3) similar to their counterparts (27·6 l, SD = 6·0). However, the highest producing cow recorded was a cull producing 41 l/d.

Table 3. Variables in fitted binary logistic models used to predict the risk of culling in a Holstein–Friesian dairy herd when the likelihood ratio of goodness-of-fit for the model turned non-significant at the 5% confidence level

Variable	Odds ratio	Mean	Animals	*P*-value
Calving ease†	0·6	1·5	66	0·37
Body condition score at last service†	4·8	2·1	66	0·04
Mastitis†	2·8	–	66	0·20
Milk protein yield at day 60 ± 5, kg†	0·1	1·2	66	0·02
Calving year†	0·9	–	66	0·43
Calving season†	1·0	–	66	0·90
Age at first calving, months‡	1·1	26·1	46	0·64
Metabolic calving weight, kg‡	1	113	46	0·63
Body condition score at last service‡	13·0	2·2	46	0·02
Genetic line‡[1]	0·8	–	46	0·83
Feeding System‡[2]	2·6	–	46	0·22
Calving season‡	1·2	–	46	0·53
Parity number§	0·8	–	68	0·46
Milk yield acceleration. l/d per d§	5·2	0·6	68	0·04
Peak milk flow rate, l/min§	1	4·1	68	0·92
Duration of milking, min§	1	9·8	68	0·92
Diseases§	0·8	–	68	0·98

† Variables in a model for culling dairy cows due to infertility
‡ Variables in a model for culling first parity dairy cows due to infertility
§ Variables in a model for culling dairy cows due to udder problem
[1] There were two genetic lines; animals selected for fat plus protein (select) and those selected to remain close to average genetic merit for fat plus protein (control) as evaluated in the United Kingdom
[2] Animals were fed either high forage (70–75%) or low forage (45–50%) diet on dry matter basis

The fitted models indicated that, for cows culled due to fertility reasons, a high BCS at last service and low milk protein yield around day 60 in lactation significantly ($P=0{\cdot}04$ and 0·02, respectively) increased the likelihood of culling, presented in Table 3. Variables such as mean daily milk yield, metabolic calving weight and BCS at calving did not significantly increase the risk of involuntary culling and were eliminated in the process of fitting the model for predicting the risk of culling cows due to infertility.

Cows with a higher than average BCS at last service were five times [Odds Ratio (OR) = 4·8] more likely to be culled due to fertility reasons. Cows with low milk protein yield at around 60 days in milk were ten percent less likely to be culled (OR = 0·1). In first parity cows only BCS at last service significantly ($P=0{\cdot}02$) increased the risk of culling due to infertility. The predicted risk of culling in first lactation cows was heavily pronounced because first parity cows with a higher than average BCS at last service were 13-times more likely to be culled.

The acceleration of milk yield showed that it had a significant effect on increasing the risk of culling cows due to udder problems ($P=0{\cdot}04$). The risk was five times higher in cows with a high rate of acceleration. Thus cows that had high rate of increase in their daily milk yield were predicted to be at higher risk of being culled than their counterparts.

Discussion

The current study demonstrated that traits indicating metabolic imbalance contribute significantly to the risk of cows being culled from the herd. Although previous studies have shown that these factors are indeed associated with culling in dairy herds (Esslemont & Kossaibati, 1997; Bascom & Young, 1998; Cozler et al. 2009; Orpin & Esslemont, 2010) the current study has shown that these factors are associated with both cows culled due to infertility and also due to udder health problems. Abnormal mobilization of body reserves is directly measurable, with reasonable precision, using energy and nitrogen balance techniques. However, the on-farm application of these techniques is not currently realistic (Ingvartsen at al. 2003). The alternative direct measurement of body mobilization based on changes in live weight and BCS give estimates which compare favourably with energy balance calculations (Coffey et al. 2001). Excessive body condition in dairy cows such as a high BCS at last service instigate health challenges (Ferguson et al. 1994). Cows with a higher than average BCS score (⩾ 3·5 on a 5-point scale) are susceptible to metabolic disorders in early lactation (Roche et al. 2009). For instance, cows developing ketosis tend to have a higher BCS than healthy cows, and a history of ketosis before service risks decrease in likelihood to conceive to that service (Gillund et al. 2001). In first lactation heifers BCS outside the range 2·75–3·5 (5-point scale) increases the possibilities of calving difficulties (Mee, 2007) which negatively affect performance in first parity than subsequent parities (Lopez et al. 2007). Similarly to a commercial set up of a dairy herd with strict controlled feeding system, in the current study cows were fed total mixed ration ad libitum, as a result there were few animals with excessive thin bodies at time of service. Since the body condition of cows increases with time in lactation (Roche et al. 2009), repeat breeders, cows not seen on heat and cows with reproductive disorders ended up having a high BCS at time of last service. Thus the results suggested that monitoring of body condition is important for timely detection of cows likely to have abnormal body conditions at the time of service.

The recorded high culling rate in LFS production system could be a function of both genetic value for milk production and nutrition of animals. However, there was no direct evidence to support the claim. It should be indicated that, for more than a decade, low milk production has ceased to be a common sole primary reason of culling in dairy herds as reported by Bascom & Young (1998). On the contrary, high-producing cows tend to be more susceptible to excessive negative energy balance (Heuer et al. 2000; Wathes et al. 2007) and in times of energy deficit the milk biochemical characteristics, in particular protein proportion, tends to decrease (Cejna & Chladek, 2005; Tena-Martinez et al. 2009). The proxy characteristic for milk sold composition used in the analysis was milk protein yield at around day 60 in lactation. Though the primary body reserve mobilized is fat during a time of energy deficit, cows may tap into protein or mineral reserves as well (Bewley & Schutz, 2008). Therefore, although culling risk was ten percent less, potentially body energy levels contributed to culling. The greater impact in first lactation animals could be because cows in parity one were still growing as compared with cows in at least second lactations. On the other hand, previous studies (Wathes et al. 2007; Cozler et al. 2009; Frelich et al. 2010) substantiate high culling rate in first parity cows due to infertility also observed in this study. This indicated the importance of this group of cows and probably one of the reasons infertility continues to be an increasingly important challenge to the dairy production.

The stress on the udder before peak lactation and the physiological stress being experienced by the cow increased the risk of being culled. Cows with high milk yield acceleration were likely to have been under physiological pressure to satisfy the increased demand for milk production due to the rapid increase in yield. This stress increased the susceptibility of cows to diseases and udder conformation related problems. Elevated SCC and mastitis incidence in some cases are resultants of energy deficit (Banos et al. 2006) but it cannot be concluded that energy deficit influenced culling in respect to udder problems in this study. The incidences of high SCC, mastitis and the udder disorders could be related to milking practice in addition to physiological stress on the udder.

The results of the study suggested that regular monitoring of metabolic imbalance such as BCS, milk protein yield at peak lactation, and milk yield acceleration could help identify cows at high risk of being culled. Body condition scoring is used to achieve good feeding efficiency by making proper adjustments in respect to herd nutrition status (Waltner et al. 1993). Thus through consistent monitoring of the traits that indicate metabolic imbalance and properly feeding lactating dairy cows, the risk of involuntary culling in dairy herds due to fertility reasons and udder health problems can be minimized.

The authors gratefully acknowledge funding from The Scottish Government (International Development Fund).

References

Banos G, Coffey MP, Wall E & Brotherstone S 2006 Genetic relationship between first-lactation body energy and later-life udder health in dairy cattle. *Journal of Dairy Science* **89** 2222–2232

Bascom SS & Young AJ 1998 A Summary of the reasons why farmers cull cows. *Journal of Dairy Science* **81** 2299–2305

Bell MJ & Roberts DJ 2006 Effect of twinning on the feed intake, performance and health of dairy cows. *Livestock Science* **107** 274–281

Bell MJ, Wall E & Russell G 2010 Risk factors for culling in Holstein–Friesian dairy cows. *Veterinary Record* **167** 238–240

Bewley JM & Schutz MM 2008 Review: an interdisciplinary review of body condition scoring for dairy cattle. *Professional Animal Scientist* **24** 507–529

Cejna V & Chladek G 2005 The importance of monitoring changes in milk fat to milk protein ratio in Holstein cows during lactation. *Journal of Central European Agricultural* **6** 539–546

Chagunda MGG, Friggens NC, Rasmussen MD & Larsen T 2006 A model for detection of individual cow mastitis based on an indicator measured in milk. *Journal of Dairy Science* **89** 2980–2998

Chagunda MGG, Romer DAM & Roberts DJ 2009 Effect of genotype and feeding regime on enteric methane, non-milk nitrogen and performance of dairy cows during the winter feeding period. *Livestock Science* **122** 323–332

Coffey MP, Emmans GC & Brotherstone S 2001 Genetic evaluation of bulls for energy balance traits using random regression. *Journal of Dairy Science* **86** 2205–2212

Cozler YL, Peccatte JR & Delaby L 2009 A comparative study of three growth profiles during rearing in dairy heifers: effect of feeding intensity during two successive winters on performances and longevity. *Livestock Science* **127** 238–247

Esslemont RJ & Kossaibati MA 1997 Culling in 50 dairy herds in England. *Veterinary Record* **140** 36–39

Ferguson JD, Galligan DT & Thomsen N 1994 Principal descriptors of body condition score in holstein cows. *Journal of Dairy Science* **77** 2695–2703

Frelich J, Slachta M & Kobes M 2010 Reasons for the culling of dairy cows on low-input mountain farms. *Journal of Agrobiology* **27** 41–48

Gillund P, Reksen O, Grohn YT & Karlberg K 2001 Body condition related to ketosis and reproductive performance in norwegian dairy cows. *Journal of Dairy Science* **84** 1390–1396

Hadley GL, Wolf CA & Harsh SB 2006 Dairy cattle culling patterns, explanations, and implications. *Journal of Dairy Science* **89** 2286–2296

Heuer C, Straalen WMV, Schukken YH, Dirkzwager A & Noordhuizen JPTM 2000 Prediction of energy balance in high yielding dairy cows with test-day information. *Journal of Dairy Science* **84** 471–481

Hovinen M & Pyörälä S 2010 Invited review: udder health of dairy cows in automatic milking. *Journal of Dairy Science* **94** 547–562

Ingvartsen KL, Dewhurst RJ & Friggens NC 2003 On the relationship between lactation performance and health: is it yield or metabolic imbalance that causes production diseases in dairy cattle? A position paper. *Livestock Production Science* **83** 277–308

Knop R & Cernescu H 2009 Effect of negative energy balance on reproduction in dairy cows. *Lucrari Stiintifice – Universitatea de Stiinte Agricole a Banatului Timisoara, Medicina Veterinara* **42** 198–205

Knight CH, Beever DF & Sørensen A 1999 Metabolic load to be expected from different genotypes under different systems. *British Society of Animal Science Occasional Publication* **24** 27–35

Kronfeld D 1976 The potential importance of the proportions of glucogenic, lipogenic and amonigenic nutrients in regard to the health and productivity of dairy cows. *Advanced Animal Physiology & Nutrition* **7** 5–26

Lopez DME, Ugarte E & Gonzalez-Recio O 2007 Impact of calving ease on functional longevity and herd amortization costs in bosque holsteins using survival analysis. *Journal of Dairy Science* **90** 4451–4457

Løvendahl P & Chagunda MGG 2006 Assesssment of fertility in dairy cows based on electronic monitoring of their physical activity. In *8th World Congress on Genetics Applied to Livestock Production*, Brasil, Belo Horizonte, August 13–18

Mee JF 2007 Prevalence and risk factors for dystocia in dairy cattle: a review. *Veterinary Journal* **176** 93–101

Mulligan FJ, Grady LO, Gath VP, Rice DA & Doherty ML 2007 Nutrition and Fertility in dairy cows. *Irish Veterinary Journal* **60** 44–49

Orpin PG & Esslemont RJ 2010 Culling and wastage in dairy herds: an update on incidence and economic impact in dairy herds in the UK. *Cattle Practice* **18** 163–172

Roche JR, Friggens NC, Kay JK, Fisher MW, Stafford KJ & Berry DP 2009 *Invited review:* body condition score and its association with dairy cow productivity, health, and welfare. *Journal of Dairy Science* **92** 5769–5801

Rushen J & de Passille AM 2006 Effects of roughness and compressibility of flooring on cow locomotion. *Journal of Dairy Science* **89** 2965–2972

SAS I.I. 2008 SAS Institute Inc (Cary, NC, USA)

Tena-Martinez MJ, Val-Arreola D, Hanks JD & Taylor NM 2009 The use of early lactation milk protein content to predict subsequent fertility performance and likelihood of culling, in commercial dairy cows. *Journal of Animal and Feed Sciences* **18** 209–220

Waiblinger S, Menke C, Korff J & Bucher A 2004 Previous handling and gentle interactions affect behaviour and heart rate of dairy cows during a veterinary procedure. *Applied Animal Behaviour Science* **85** 31–42

Waltner SS, McNamara JP & Hillers JK 1993 Relationships of body condition score to production variables in high producing holstein dairy cattle. *Journal of Dairy Science* **76** 3410–3419

Wathes DC, Brickell JS, Bourne NE, Swali A & Cheng Z 2007 Factors influencing heifer survival and fertility on commercial dairy farms. *Animal* **2** 1135–1143.