The effect of organic status and management practices on somatic cell counts on UK dairy farms

M. J. Haskell,¹ F. M. Langford, M. C. Jack, L. Sherwood, A. B. Lawrence, and K. M. D. Rutherford

Animal Behaviour and Welfare, Sustainable Livestock Systems, Scottish Agricultural College, Edinburgh, EH9 3JG, United Kingdom

ABSTRACT

The numbers of organic dairy farms are increasing in the United Kingdom and in other parts of the world. On organic farms, the use of veterinary medicines is restricted. Because of this, there is concern that cow health is poorer on these farms. As udder health is primarily maintained by the use of antimicrobials, the effect of organic status on mastitis and somatic cell counts (SCC) is important to investigate. The aim of this study was therefore to determine whether the organic status and other management factors affect SCC. A group of 80 dairy farms was used in the study: 40 organic farms and 40 nonorganic farms. The farms were recruited in pairs, and each organic:nonorganic pair was matched for herd size, housing type, genetic merit for milk production and geographical location. Somatic cell count data were extracted from national databases for a standard year (2004), and analyzed using stepwise logistic regression models. The organic status of the farm did not appear in the final model, indicating no major influence of organic status on SCC. There were, however, several effects of management on SCC. Somatic cell counts were lower on farms where the udders were not cleaned or cleaned only when dirty. Somatic cell counts were also lower on farms that kept cows in larger management groups and where the majority, but not all cases of mastitis are treated with antimicrobials. It can be concluded that the control measures used on the organic farms in this study are at least as effective as those used on nonorganic farms in controlling SCC. Other management factors are influential and attention to these factors will allow farmers to reduce SCC.

Key words: dairy cow, somatic cell count, organic farming

INTRODUCTION

In recent years in the United Kingdom, there has been an expansion in the number of dairy farmers converting to organic management systems. Organic

produce appeals to consumers who are concerned about their health, product quality, the effect of conventional agricultural systems on the environment, and animal welfare. Not only are organically farmed cows fed on foodstuffs grown with minimal use of pesticides, but there are also different regulations for chemically synthesized drug use and housing standards for the animals. Although many organic producer groups claim that the level of animal welfare is higher on organic farms compared with nonorganic farms, there is concern that this may not always be so (Sundrum, 2001; Hovi et al., 2003). Independent research is required to address this issue.

The prevalence of mastitis and subclinical mastitis is important to consider. Mastitis is a serious animal welfare problem and causes losses to producers through reduced yield and the cost of treatment (Mrode and Swanson, 1996; Kossaibati and Esslemont, 1997). The presence of high SCC in individual cows indicates subclinical levels of mastitis (Reneau, 1986). As farmers are penalized for having high SCC in the bulk tank, the reduction of SCC below the penalty level at the herd level is a goal in its own right for farmers. To identify methods farmers might use to reduce SCC on their farms, many studies have investigated the relationship between farm hygiene and management factors on the bulk milk tank SCC (**BTSCC**; Barkema et al., 1998a; Barnouin et al., 2004). More recently, SCC from individual cows on each day of milk recording (test days) have been used (e.g., Lievaart et al., 2007). Most of the factors that influence SCC relate to cleanliness and hygiene in all aspects of the farming routine. The use of hygienic practices during milking is of primary importance (Moxley et al., 1978; Bartlett et al., 1992; Goodger et al., 1993; Faye et al., 1997; Barkema et al., 1998a; Barnouin et al., 2004). The cleanliness of the cows themselves, and of the housing, pasture, yards, bedding, and parlor have also been shown to be important (Hutton et al., 1991; Bartlett et al., 1992; Goodger et al., 1993; Faye et al., 1997; Barnouin et al., 2004; De Vliegher et al., 2004; Green et al., 2008).

Of particular relevance to organic dairying is the finding that the use of antimicrobials is important in reducing SCC. In studies on nonorganic farms, lower

Received February 4, 2009.

Accepted April 9, 2009.

¹Corresponding author: marie.haskell@sac.ac.uk

cell counts were associated with farms that used antimicrobials to control mastitis (Barkema et al., 1998a), involved the veterinarian in the control of mastitis (Moxley et al., 1978), and/or used dry cow therapy (Goodger et al., 1993; Barkema et al., 1998a), which typically involves the use of antimicrobial treatment at the end of each lactation. However, the routine use of antimicrobials is discouraged in organic systems. Alternative remedies, such as homeopathy, can be used for the treatment of disease, and measures should be taken to “enhance the immune defense” of the animals (Lund, 2006), such as the use of good husbandry and good quality housing. Within the European Union, antimicrobials can be used in acute cases such as for clinical mastitis, but the withdrawal period for sale of milk is longer on organic farms than for nonorganic farms, and cows are allowed to be treated no more than 3 times during one lactation (CEC, 2004). Higher SCC are permissible for farmers selling organic milk. Because of this apparent conflict between what has been shown to be good practice in terms of herd health and the principles of organic farming, there is concern that cows on organic farms may be suffering prolonged exposure to disease, reducing their welfare (Hovi et al., 2003; Vaarst et al., 2005). There have been some studies on SCC on organic farms, but there is little consensus. Higher levels of SCC have been found on organic farms in studies comparing a sample of organic farms with a sample of nonorganic farms (United Kingdom: Hovi and Roderick, 2000; Switzerland: Roesch et al., 2007). A similar result was shown in a study in which the SCC level found in a group of organic farms was compared with the published national average (United Kingdom: Weller and Bowling, 2000). Busato et al. (2000) found lower levels than that found in another previous independent study in Switzerland, whereas others have shown no difference between organic and nonorganic herds (e.g., Sato et al., 2005; Fall et al., 2008). Large-scale studies using information from individual cows may be informative.

Therefore, the aim of this study was to assess the effects of organic production systems on SCC by comparing the somatic cell counts on organic and nonorganic farms across Great Britain using test-day records from individual cows. Information on housing and management practices were gathered from these farms, so it was also possible to investigate the relationships between SCC and farm management and hygiene practices.

MATERIALS AND METHODS

Farm Recruitment and Characteristics

Forty organic and 40 matched nonorganic farms were recruited for this study. As described in Rutherford et

al. (2008), the organic farms were recruited first via organic certification bodies, dairy consultants, or had participated in previous studies. A total of 355 initial contact letters were sent out, yielding 102 positive replies. The farms used in the study were limited to those that had predominantly Holstein/Holstein-Friesian animals and had a herd size of greater than 50 cows. No zero-grazing farms were included in the study and all participating farms kept cows housed for at least part of the winter period. All farms milked their cows twice daily in the morning and afternoon. On these criteria, 50 of the 102 farms were identified as being suitable for the study and the final 40 were chosen from these 50. To account for the effect of herd size, type of housing (free-stall vs. straw yard housing), genetic merit for milk production, and geographical location (which affects climate), all of which may affect SCC, an organic farm was paired with a nonorganic farm having the same characteristics. Nonorganic farms that matched these requirements were recruited to the study through Scottish Agricultural College's contacts in the dairy industry and a national dairy consultancy firm. Approximately 500 letters were sent out to recruit the 40 nonorganic farms that matched the 40 organic farms. Thirty-one pairs of free-stall farms and 9 pairs of straw yard farms were recruited. Farms were located from lowland Scotland, throughout Wales, and down to the south coast of England.

Farm Visits

All of the farms were visited once during the fall (September to October) and once during the spring (March to June) in a period between 2004 and 2006, with the majority of the farms visited in consecutive seasons. Matched pairs of organic and nonorganic farms were both visited within a 2-wk period. Every farmer was interviewed to obtain information about farm management, housing, husbandry, and animal treatment practices during one of the farm visits. Information on the milking hygiene practices, the routines for treating mastitis and suspected mastitis cases, frequency of servicing parlor equipment, grazing duration, and herd size was gathered during this interview.

Data Analysis

All farms were registered with 1 of the 2 major milk recording companies in Great Britain (Cattle Information Services and National Milk Records). Test-day records for SCC were extracted from the databases of these companies for all cows on all 80 farms for the year 2004. As some farms have milk-recording visits every 4 wk and some every 6 wk, records from December

2003 and January 2005 were also eligible. Cows with lactation lengths of longer than 305 d were excluded, as lactations longer than this were generally found to be due to recording errors. A similar number of cows were excluded from organic and nonorganic farms. Only cows with 5 or more test-day records were included in the analysis. Five or more test-days are necessary to give an adequate representation of the lactation-average SCC for that cow (Mrode and Swanson, 1996).

Genstat (Genstat 8th ed., Lawes Agricultural Trust, VSN International Ltd., Oxford, UK) was used for all statistical analyses. Somatic cell counts were log-transformed using natural logarithms, and log-transformed values were used in the analysis (Mrode and Swanson, 1996). Linear mixed models were fitted to identify the factors influencing SCC. Farm identity, cow within farm, and lactation number within cow (to account for cows that had test days spanning more than one lactation) were fitted as random effects. Explanatory variables were fitted as fixed effects. Previous research has shown that several variables affect somatic cell count. Some of these variables would potentially have affected our results, so were included as fixed effects. These variables are routinely included in genetic evaluations for SCC. The number of lactations, the milk yield of the cow in that lactation, and the season of calving are all factors known to affect SCC (Mrode et al., 1998; Busato et al., 2000; De Vliegher et al., 2004; Green et al., 2008), so this data was also extracted from the database and included in the analysis. To fit age at first calving, we used the information on this from the farmer interview. Days in milk and DIM² were fitted to account for the nonlinear relationship between milk yield and SCC (Mrode and Swanson, 1996). The latter covariates were centered to prevent outliers affecting numerical stability in the fitted models. To investigate other factors of interest measured in the course of this project (e.g., organic vs. nonorganic, herd size), basic graphs were used to assess linearity between the response and each of the explanatory variables. Continuous nonlinear variables were split into quartiles, resulting in factors with 4 levels. When an explanatory variable varied linearly with the response it was entered into the analysis as a variate. Otherwise, it was entered into the analysis as a factor. Discrete explanatory variables (e.g., organic vs. nonorganic) were also analyzed as factors.

Preliminary univariate linear mixed model analysis with REML was undertaken with each explanatory variable (both variates and factors as fixed effects; e.g., organic vs. nonorganic, lactation number, interview variables) to identify variables that explained variation in SCC when assessed individually. Explanatory variables that were significant at $P < 0.25$ within univariate

analyses were then considered in multi-variable models, again using linear mixed models with REML.

Models were built using forward stepwise techniques, adding in each explanatory variable to the fixed effect model in turn. Those explanatory variables having the same P -value in the univariate analyses were added in order of the highest Wald-statistic value from the univariate analysis. Variables within the final model were chosen based on their additional significance when all other explanatory variables in the model had been fitted. During the model building process, explanatory variables that shared variation were tested individually in the model. Where significant sharing occurred, and where the literature indicated that there was a clear cause and effect relationship between the 2 variables, the effect variable was discarded. Where there was no evidence for cause and effect, the variable explaining more of the variation was kept in the model, with the other being discarded. Wald statistics (**W**) are presented in the results, with their corresponding degrees of freedom shown in subscript. The fit of the final model was assessed by correlating the fitted values from the model (i.e., predicted value for SCC for each cow) with the actual SCC values. A generalized linear mixed model with a binomial distribution was used to explore certain findings further, such as whether organic farms had different group sizes than nonorganic farms.

We intended to assess the differences between farms with low, medium, and high SCC as was done by Barkema et al. (1998a) and others since (e.g., Barnouin et al., 2004; De Vliegher et al., 2004). This is done because certain pathogens are associated with consistent herd levels of BTS_{CC} (Barkema et al., 1998a), and management practices may have different effects depending on the pathogen present (Barkema et al., 1998b). Visually, the distribution of the individual cow cell counts fitted the categories used by Barkema et al., (1998a): low $\leq 150,000$, medium = 150,000 to 250,000, and high $> 250,000$ cells/mL. However, the studies in which this approach was used had larger numbers of farms than we had in this study (300 farms in Barkema et al., 1998a; 1998b). Furthermore, when the farm mean cell counts were plotted, the distribution of the farms across the categories was very uneven (low = 13; medium = 42; high = 25), which meant that the results of any multi-variable analysis would be unreliable. It was decided, therefore, that all the farms would be analyzed together.

RESULTS

There were 5,702 cows with 5 or more consecutive SCC from test-day records included in the analysis from

Table 1. Effect of premilking udder-cleaning method on SCC¹

Method of udder cleaning before milking	Mean ($\times 1,000$ cells/mL)	SEM
No contact with udder or wash only when dirty, $n = 9$	31.25	0.002
Dry wipe only, $n = 39$	215.35	0.001
Dry wipe and additional washing, $n = 7$	169.40	0.002
Wet wipe, $n = 18$	200.79	0.001
Washing with water, $n = 2$	265.67	0.003

¹Data presented are back-transformed predicted means from the final model. Back-transformed standard errors of means are given. Information not available for 5 farms.

the 40 organic and 40 nonorganic farms. The average cell count was 214,000 cells/mL (standard deviation = 80,000 cells/mL). The national average in that year (2004) was 187,000 cells/mL (DairyCo, 2009). The organic and nonorganic farms had similar herd sizes [organic = 150 ± 26 ; nonorganic = 145 ± 27.5]. Whereas the farms had similar genetic merit for milk production (UK Profit Index: organic = 20.2; nonorganic = 21.8), the recruited organic farms had a lower average milk yield (organic = $7,311.5 \pm 1,477$; nonorganic = $8,436 \pm 1,259$ L/cow per lactation).

There was no effect of organic status or of housing type (straw vs. free-stalls) as neither of these variables appeared in the final model. Somatic cell counts increased with lactation number ($W_9 = 1,594.72$, $F = 177.19$, $P < 0.001$) and varied with stage of lactation in a quadratic manner (DIM: $W_1 = 1,690.64$, $F = 1,690.64$, $P < 0.001$; DIM²: $W_1 = 376.84$, $F = 376.84$, $P < 0.001$). Somatic cell counts were not affected by age at first calving in this study. Somatic cell counts were highest in the summer period (June to August: $W_3 = 30.23$, $F = 10.08$, $P < 0.001$). Somatic cell count was associated with the individual cow's milk yield for that lactation ($W_1 = 333.17$, $F = 333.17$, $P < 0.001$), with higher-yielding cows having lower cell counts. The correlation between the fitted values from the final model and the actual values was 0.72.

There were several effects of management practice (Tables 1 and 2). The method used to clean the udder before milking affected SCC. Somatic cell counts were lower if the udder was not touched or washed only if dirty, compared with alternative strategies (udder always washed with water, dry wipes used, dry wipes with additional washing used, or wet wipes used; $W_4 = 16.40$, $F = 4.10$, $P < 0.01$; Table 1). The size of the management groups during housing also affected SCC, with the largest group sizes having the lowest cell counts ($W_3 = 9.06$, $F = 3.02$, $P < 0.05$; Table 2). There was no difference between the organic and nonorganic farms in the way in which the udder was washed ($W_1 = 0.36$, $P > 0.05$), nor any difference in the management group size (Langford et al., 2009). The frequency of antimicrobial use also affected SCC ($W_3 = 7.87$, $F = 2.62$,

$P < 0.05$). Of the 4 categories of usage, farms which treated 60 to 90% of mastitis cases with antimicrobials (or 10 to 40% of the cases without antimicrobials) had the lowest SCC, compared with the 2 lower and the higher antimicrobial usage categories.

DISCUSSION

Overall, the results showed that there were no major differences in SCC between organic and nonorganic farms in Great Britain when test-day records were used. This is important as concern has been expressed within the European Union that the welfare of cows on organic farms could be compromised by the regulations regarding use of antimicrobials and the longer withdrawal periods for milk. There are varying reports in the literature. In the United States, where the use of antimicrobials is prohibited on organic farms, Sato et al. (2005) found no difference in SCC between a group of organic farms and their nonorganic neighbors. A study in Sweden (Fall et al., 2008) also found no difference between an organic and a nonorganic herd. However, other studies have found higher SCC in cows on organic farms early in lactation (Roesch et al., 2007) and overall (Hovi and Roderick, 2000; Hardeng and Edge, 2001). There are also varying reports from studies investigating only organic farms. Somatic cell count levels in organic farms in the UK been reported by Weller and Bowling (2000) to be higher than the national average. In contrast, however, a study in Switzerland found SCC on organic farms to be lower than that shown in a previous independent study (Busato et al., 2000). Similar trends are found in studies assessing cases of mastitis on organic and nonorganic farms. Using the California Mastitis Test, Roesch et al. (2007) found no difference between organic and nonorganic farms in the number of positive samples, whereas Hovi and Roderick (2000) reported higher mastitis rates on organic farms than nonorganic farms during the dry period, but the reverse during the lactating period. The fact that different studies come up with different findings is likely due to the attributes of the particular population of farms used in each study. In this study an effort was

Table 2. Effects of group size and frequency of antimicrobial treatment on SCC¹

Class ²	Maximum management group size (no. of cows)			
	Up to 80 (n = 18)	80–109 (n = 21)	110–140 (n = 16)	Over 140 (n = 22)
Mean, ×1,000 cells/mL	181.68	189.09	196.81	63.58
SEM	0.001	0.001	0.001	0.001
Mastitis cases treated with antimicrobials (%)				
Class ³	0–20% (n = 13)	25–50% (n = 11)	60–90% (n = 7)	100% (n = 43)
Mean, ×1,000 cells/mL	171.10	187.21	54.18	245.24
SEM	0.002	0.002	0.002	0.001

¹Data presented are back-transformed predicted means from the final model and back-transformed standard errors of means.

²Data unavailable for 3 farms.

³Data unavailable for 6 farms.

made to compare “like with like,” and the organic and nonorganic farm populations were matched for factors such as housing type and grazing season, which should have reduced some of the noise in the data. Test-day records were also used, rather than BTSCC samples, which allowed variation between cows to be assessed. In future studies, it may also be beneficial to incorporate bacteriological sampling, as different agents cause different levels of SCC response (Barkema et al., 1998b).

The results from this study in the UK indicate that the control measures for SCC used on organic farms are at least as effective as those used on nonorganic farms in controlling SCC. There is also some evidence that not treating every new case of mastitis with antimicrobials might be beneficial to SCC. Alternative control methods could be used in the first instance. In this study, the farmer interview showed that there were differences in the strategies that organic and nonorganic farmers used to treat mastitis (Langford et al., 2009). The majority of organic farmers treated the early stages of mastitis with alternative remedies and did not use antimicrobials unless the case became clinical or took too long to clear. The nonorganic farmers used antimicrobials at the first sign of mastitis. There was variation within the organic farmers in how many cases were treated with antimicrobials, and the result is based on this variation.

Other studies have also shown an effect of increasing lactation number (e.g., Busato et al., 2000) and stage of lactation on SCC (Mrode and Swanson, 1996). Several previous studies have also shown that parlor hygiene is important in maintaining udder health. Whereas it may be assumed that thorough washing before milking reduces SCC, it is often found that not touching udders that are clean is associated with lower SCC (Barnouin et al., 2004). This is because wetting an infected udder allows contaminated water to seep in to the milking unit, allowing other cows to be infected (NMC, 1978;

Bartlett et al., 1992). Equally, it has been shown that the use of towels or wipes on several cows is not good practice (Bartlett et al., 1992; Barkema et al., 1998a), and that the use of one towel per cow is associated with low SCC (Faye et al., 1997). Our results concur with these studies and showed that the farms where the udder is not washed or washed only when dirty had the lowest SCC. In some cases it was observed that wipes were used on more than one cow, which would spread infection.

This study showed that the farms having cows in the largest groups had lower cell counts. It is important to note that these practices may not necessarily be directly related to the SCC, as this type of analysis is only capable of detecting relationships between the variables. The absolute test of a co-relationship between variables would be to perform a controlled experiment, but by practical necessity, this would be on one or a few farms. Whereas no other reports of a direct relationship between group size and SCC are currently available, a relationship between herd size and SCC has been reported, but shows a contrasting result to that shown in the present study. Doherr et al. (2007) found an increase in subclinical mastitis with increasing numbers of cows on the farm, whereas Lievaart et al. (2007) found that SCC increased with herd size, at least for herds that had medium and high herd-level SCC. Higher clinical mastitis has also been reported for farms with higher numbers of cows (Bartlett et al., 1992). Exact herd sizes and size of management groups are often not reported, which would allow a comparison across studies. It is possible that the relationship between group size and SCC is not direct. Larger farms may be more profitable, have more resources to put toward good cow facilities, and encourage good parlor hygiene and animal care practices. A study that directly compared group size and SCC would be needed to determine cause and effect.

In conclusion, the study found no difference in SCC between organic and nonorganic dairy cows on 80 farms in Great Britain. Several management practices that affect SCC were shown that may inform best practice initiatives for dairy farmers.

ACKNOWLEDGMENTS

We thank all the farmers who participated in the study. This project was funded by the UK Department for the Environment, Food and Rural Affairs (Defra). We are grateful to R. Mrode (Scottish Agricultural College, Penicuik, UK) for advice on analysis. Statistical advice was provided by I. Nevison, of Biomathematics and Statistics Scotland (BioSS). We thank the following for access to their farmer membership lists: Organic Milk Suppliers Co-Operative, Scottish Organic Producers Association, The Soil Association, and Kingshay Farming Trust, and to Cattle Information Services and National Milk Records for access to their databases.

REFERENCES

- Barkema, H. W., Y. H. Schukken, T. J. G. M. Lam, M. L. Beiboer, G. Benedictus, and A. Brand. 1998a. Management practices associated with low, medium, and high somatic cell counts in bulk milk. *J. Dairy Sci.* 81:1917–1927.
- Barkema, H. W., Y. H. Schukken, T. J. G. M. Lam, M. L. Beiboer, H. Wilmsink, G. Benedictus, and A. Brand. 1998b. Incidence of clinical mastitis in dairy herds grouped in three categories by bulk milk somatic cell counts. *J. Dairy Sci.* 81:411–419.
- Barnouin, J., M. Chassagne, S. Bazin, and D. Boichard. 2004. Management practices from questionnaire surveys in herds with very low somatic cell score through a national mastitis program in France. *J. Dairy Sci.* 87:3989–3999.
- Bartlett, P. C., G. Y. Miller, S. E. Lance, and L. E. Heider. 1992. Environmental and managerial determinants of somatic cell counts and clinical mastitis incidence in Ohio dairy herds. *Prev. Vet. Med.* 14:195–207.
- Busato, A., P. Trachsel, M. Schallibaum, and J. W. Blum. 2000. Udder health and risk factors of subclinical mastitis in organic dairy farms in Switzerland. *Prev. Vet. Med.* 44:205–220.
- Commission of the European Communities. 2004. Consolidated text (01/05/04) of Council Regulation No 2092/91 on organic production. *Off. J. L198*: 1–15.
- DairyCo. 2009. UK Milk Hygienic Quality. Back Data. <http://www.mdcdatum.org.uk/backdata/HygenicQuality.xls> Accessed Feb. 3, 2009.
- De Vlieghe, S., H. Laevens, H. W. Barkema, I. R. Dohoo, H. Stryhn, G. Opsomer, and A. De Kruif. 2004. Management practices and heifer characteristics associated with early lactation somatic cell count of Belgian dairy heifers. *J. Dairy Sci.* 87:937–947.
- Doherr, M. G., M. Roesch, W. Schaeren, M. Schallibaum, and J. W. Blum. 2007. Risk factors associated with subclinical mastitis in dairy cows on Swiss organic and conventional production system farms. *Vet. Med.* 52:487–495.
- Fall, N., U. Emanuelson, K. Martinsson, and S. Jonsson. 2008. Udder health at a Swedish research farm with both organic and conventional dairy cow management. *Prev. Vet. Med.* 83:186–195.
- Faye, B., F. Lescouret, N. Dorr, E. Tillard, B. MacDermott, and J. MacDermott. 1997. Interrelationships between herd management practices and udder health status using canonical correspondence analysis. *Prev. Vet. Med.* 32:171–192.
- Goodger, W. J., T. Farver, J. Pettetier, P. Johnson, G. De Snayer, and J. Galland. 1993. The association of milking management practices with bulk tank somatic cell counts. *Prev. Vet. Med.* 15:235–251.
- Green, M. J., A. J. Bradley, G. F. Medley, and W. J. Browne. 2008. Cow, farm and herd management factors in the dry period associated with raised somatic cell counts in early lactation. *J. Dairy Sci.* 91:1403–1415.
- Hardeng, F., and V. L. Edge. 2001. Mastitis, ketosis and milk fever in 31 organic and 93 conventional Norwegian dairy herds. *J. Dairy Sci.* 84:2673–2679.
- Hovi, M., and S. Roderick. 2000. Mastitis and mastitis control strategies in organic milk. *Cattle Pract.* 8:259–264.
- Hovi, M., A. Sundrum, and S. M. Thamsborg. 2003. Animal health and welfare in organic livestock production in Europe: Current state and future challenges. *Livest. Prod. Sci.* 80:41–53.
- Hutton, C. T., L. K. Fox, and D. D. Hancock. 1991. Risk factors associated with herd-group milk somatic cell count and prevalence of coagulase-positive staphylococcal intramammary infections. *Prev. Vet. Med.* 11:25–35.
- Kossabati, M. A., and R. Esslemont. 1997. The costs of production diseases in dairy herds in England. *Vet. J.* 154:41–51.
- Langford, F. M., K. M. D. Rutherford, M. C. Jack, L. Sherwood, A. B. Lawrence, and M. J. Haskell. 2009. A comparison of management practices, farmer-perceived disease incidence and winter housing on organic and non-organic dairy farms in the UK. *J. Dairy Res.* doi:10.1017/S00220299-8-3622.
- Lievaart, J. J., H. W. Barkema, W. D. J. Kremer, J. van den Broek, J. H. M. Verheijden, and J. A. P. Heesterbeek. 2007. Effect of herd characteristics, management practices and season on different categories of the herd somatic cell count. *J. Dairy Sci.* 90:4137–4144.
- Lund, V. 2006. Natural living—A precondition for animal welfare in organic farming. *Livest. Sci.* 100:71–83.
- Moxley, J. E., B. W. Kennedy, B. R. Downey, and J. S. T. Bowman. 1978. Survey of milking hygiene practices and their relationships to somatic cell counts and milk production. *J. Dairy Sci.* 61:1637–1644.
- Mrode, R. A., and G. J. T. Swanson. 1996. Genetic and statistical properties of somatic cell count and its suitability as an indirect means of reducing the incidence of mastitis in dairy cattle. *Anim. Breed Abstr.* 64:847–857.
- Mrode, R. A., G. J. T. Swanson, and M. S. Winters. 1998. Genetic parameters and evaluations for somatic cell counts and its relationship with production and type traits in some dairy breeds in the United Kingdom. *Anim. Sci.* 66:569–576.
- National Mastitis Council. 1978. Current Concepts of Bovine Mastitis. 2nd ed. Natl. Mastitis Council, Inc., Washington, DC.
- Reneau, J. K. 1986. Effective use of dairy herd improvement somatic cell counts in mastitis control. *J. Dairy Sci.* 69:1708–1720.
- Roesch, M., M. G. Doherr, W. Schären, M. Schallibaum, and J. W. Blum. 2007. Subclinical mastitis in dairy cows in Swiss organic and conventional production systems. *J. Dairy Res.* 74:86–92.
- Rutherford, K. M. D., F. M. Langford, M. C. Jack, L. Sherwood, A. B. Lawrence, and M. J. Haskell. 2008. Hock injury prevalence and associated risk factors on organic and nonorganic dairy farms in the United Kingdom. *J. Dairy Sci.* 91:2265–2274.
- Sato, K., P. C. Bartlett, R. J. Erskine, and J. B. Kaneene. 2005. A comparison of production and management between Wisconsin organic and conventional dairy herds. *Livest. Prod. Sci.* 93:105–115.
- Sundrum, A. 2001. Organic livestock farming, a critical review. *Livest. Prod. Sci.* 67:207–215.
- Vaarst, M., S. Padel, M. Hovi, D. Younie, and A. Sundrum. 2005. Sustaining animal health and food safety in European organic livestock farming. *Livest. Prod. Sci.* 94:61–69.
- Weller, R. F., and P. J. Bowling. 2000. Health status of dairy herds in organic farming. *Vet. Rec.* 146:80–81.