A study of the somatic cell count (SCC) of Irish milk from herd management and environmental perspectives

Project Number 5399

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December, 2009.

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1. Summary

The objective of this study was to investigate the herd management practices associated with somatic cell count (SCC) and total bacteria count (TBC), to geographically analyse SCC on a national basis, to investigate cow factors associated with SCC and to estimate the milk loss associated with high SCC across parities. From the 400 farms surveyed during farm visits throughout spring and winter, a profile of herd management was developed and the associations between management practices and milk SCC and TBC were established. Management practices associated with low SCC included the use of dry cow therapy, participation in a milk recording scheme, the use of teat disinfection post-milking, a higher frequency of cleaning and increased farm hygiene. Management practices associated with low TBC included the use of heated water in the milking parlour, participation in a milk recording scheme, tail clipping of cows at a frequency greater than once per year and increased farm hygiene. The spatial analysis showed that the south of the country had the greatest density of milk-recording herds. Approximately 60% of all herds in the study were from four counties (Cork, Kerry, Limerick and Tipperary). Average bulk tank SCC increased from 110,264 cells/mL in 2003 to 118,782 cells/mL in 2005, followed by a decrease to 108,454 cells/mL in 2007. Spatial clustering of high SCC scores was not observed (i.e., SCC on one farm was not related to SCC on other farms), which is consistent with mastitis being a herd problem as opposed to an area-based problem. SCC increased with parity from 97,000 cells/mL in parity 1 to 199,000 cell/mL in parity 6. SCC decreased between the period 5 to 35 days in milk (DIM) and 36 to 65 DIM, and increased thereafter. Cows calving in the months of January and September were associated with lower average 305 day SCC. The rate of increase in SCC from mid to late lactation was greatest in older parity animals. There was a test day milk loss of 1.43, 2.08, 2.59, 2.56 and 2.62 litres (parities 1 to 5, respectively) associated with an increase of SCC category from <51,000 to >400,000 cells/mL. When SCC was adjusted (test day SCC/dilution estimate, and test day SCC + (-ß)(test day milk yield)) to account for milk yield, similar trends in milk loss were observed. Alternatively, adjusting SCC (SCC*test day milk yield/mean test day milk yield) to account for milk yield showed an increase in test day milk with increasing SCC category. The results from this

study highlight that adherence to best milking/farming practice will help reduce SCC and TBC on farms. The results contribute to the knowledge relating to SCC through increasing the accuracy of milk loss due to SCC and management practices associated with SCC. The results in the study can also be used in the development of strategies to reduce SCC on farms.

2. Introduction

Raw milk quality encompasses factors relating to composition (butterfat, protein, lactose, milk solids, etc.), udder health (mastitis infection, SCC), and hygiene (total bacterial count, thermoduic bacteria, psychotropic bacteria). Milk SCC is a key component of national and international regulation for milk quality and an indicator of udder health and of the prevalence of clinical and subclinical mastitis in dairy herds. Somatic cell count from healthy, non-infected glands should be lower than 200,000 cells/ml and SCC between 200,000 and 300,000 cells/ml is indicative of a degree of infection or initial stages of infection and that general udder health is decreasing (Dohoo and Leslie, 1991) or the cow is infected with a form of mastitis (Smith, 1996).

There are many reasons why it is important to reduce somatic cell count (SCC) in the dairy cattle population. SCC can result in serious economic losses, impaired animal welfare and consumer and ethical concerns. Consumers now expect their food to come from healthy animals and to be of high quality. Antibiotics are extensively used worldwide for treating clinical mastitis (CM) and SCC, implying an increased risk of residues in milk and of the development of antibiotic resistance, which is considered to be a major public health threat (Hogan, 2005). Although some countries have milk SCC legislative limits above the EU standard of 400,000 cells/ml, many milk purchasing standards and milk quality advisory programmes are encouraging production of milk within the EU threshold. The European rules have essentially been adopted as the international export standard.

There are an increasing number of incentives and penalties for milk quality being applied by milk processors across the world. Milk quality can have a significant impact on milk processing efficiency and product quality (Olson and

Mocquat, 1980; Kitchen, 1981). As SCC increases the processability of milk decreases and there is an increased loss of fat and casein (Politis and Ng-Kwai-Hang, 1988a; Ma et al., 2000). There is also a reduced curd firmness due to increase SCC (Politis and Ng-Kwai-Hang, 1988b; Ma et al., 2000). High SCC milk may also adversely affect the quality of pasteurised liquid milk and reduced its shelf life (Janzen, 1972; Ma et al., 2000; Barbano et al., 2006). A decreased sensory quality is also associated with increased SCC (Janzen, 1972). Increased breakdown of casein and milk fat was associated with high SCC (Politis and Ng-Kwai-Hang, 1988a; Santos et al., 2003; Barbano et al., 2006). It has been shown that an increased SCC decreases cheese yield (Barbano et al., 1991; Klei et al., 1998). Santos et al. (2003) documented that an off-flavour occurred faster in high SCC milk compared to low SCC milk. Gilmour and Rowe (1990) reported that bacteria in milk can cause spoilage of milk and taints on the surface of butter.

Berry et al. (2006) carried out a study of milk SCC levels from 3 milk processors in Ireland, which accounted for approximately 40% of national output. Ireland and the UK had a similar trend in milk SCC with a downward trend between 1994 and 2000 from just under 330,000 to 241,000 cells/mL, but with a gradual increase thereafter, up to 251,000 cells/mL in 2004. The decline may be in some part due to a dilution effect of greater yields per cow (Emanuelson and Funke, 1991). Lacy-Hulbert (2006) reported that New Zealand mirrors the general worldwide picture with increase in milk SCC slowing down or becoming stagnated over the past decade. The latest results and trends from the U.S. Department of Agriculture (herds participating in the Dairy Herd Improvement (DHI) scheme) show a reduction in SCC between 2001 and 2004, with a slight increase in 2005 followed by a decrease to 2007 (Pocknee, 2009).

Østerås and Sølverød (2005) reported that in Norway there have been improvements in the SCC from around 250,000 cells/ml in the early 1980s to an arithmetic mean of 140,000 in the late 1990s with geometric means of 112,000 cells/ml and 115,000 cells/ml recorded in 2002 and 2004, respectively. Similarly bulk tank SCC in The Netherlands increased from 200,000 cells/ml in 1999 to 227,000 cells/ml in 2003 (Sampimon et al., 2005). The Danish Dairy Board (2009) have shown a general decrease in SCC from 1999 (252,367 cell/mL) to 2005

(221,002 cell/mL), however there was an increase from 2005 to 2007 (234,087 cells/mL). In Australia, SCC has generally decrease since the late 1990s to 2004 (204,000 cells/mL) (Brightling et al., 2005), however the average of 2003 to 2005 was 250,000 cell/mL (Reneau, 2007). Average milk SCC for 2003 to 2005 was 110,000, 200,000, 155,000 and 300,000 for Switzerland, UK, New Zealand and the US, respectively (Reneau, 2007).

Total bacterial count (TBC) is the total number of living bacteria per ml of milk. An increase in TBC can be related to mastitis organisms, environmental contaminants, dirty milking equipment or failure of refrigeration (Blowey and Edmondson, 1995). Additionally, milk quality parameters have to be within certain thresholds as outlined in European law 1.2 of 853 of 2004; TBC must not exceed 100,000 cell/ml, based on a geometric average over two months with at least two tests per month. High TBC can also have a negative effect on the processability of dairy products. Recent research indicated a general tendency for bulk tank TBC in Ireland to decrease between the years of 1994 to 2003, but this was followed by an increase between 2003 and 2004 (Berry et al., 2006).

Costs related to mastitis and high SCC are extensive. In Ireland, it has been speculated that the incidence of mastitis is approximately 25% per year, with an average case costing approximately €71.84/cow (Berry and Amer, 2005), which accumulates to approximately €20 million for the countries dairy herd (calculated using 1.1 million dairy cows in Ireland, (CSO, 2009)).

Like many other economically important traits in dairy cattle, SCC and mastitis is multifactorial. The incidence of high SCC in a herd is associated with the cow exposure to causative pathogens in the surrounding environment as well as the cows' level of resistance. Risk factors associated with high SCC are often related to primary management practices, including milking equipment and technique, housing, cleanliness of the environment, hygienic quality of water and feed, preventive health measures and stress (Howell, 1972; Pankey, 1984; Bartlett et al., 1992; Crist et al., 1997; Barkema et al., 1999a; Schreiner and Ruegg, 2003; Chassagne et al., 2005). Secondary factors such as parity, season, lactation stage, breed, udder conformation and milk production are also known to be associated with mastitis (Barkema et al., 1998a; Barkema et al., 1998b; Schukken et al., 1990; Zwald et al., 2006; Hagnestam et al., 2007; Nyman, 2007).

Ireland's dairy industry is predominantly a seasonally calving system, with the Holstein-Friesian cow as the main breed. This seasonal system of production is practiced in Ireland to maximise the utilisation of grass in the diet, which is cheaply produced in Ireland's mild and temperate climate. However, little mastitis work has been related to seasonal grass based systems, which could have a large impact on the pathogen load of the cow's environment and the management of the cow. Most studies on management and cow factors have been on housed cows or cows with shorter grazing seasons then Ireland. Additionally the dilution effect of milk yield on SCC for individual parities has not been studied and this could have a major impact on the association between SCC and milk yield. Thus the objectives of this study were: to quantify the association between management practices and SCC and TBC, to geographically map SCC levels across Ireland, to detect the association between cow factors and SCC and to estimate the association between milk yield and SCC .

3. Farm Management Factors Associated with Bulk Tank Somatic Cell Count in Irish Dairy Herds during 2006/07

Objective: To determine the proportion of Irish farmers undertaking different management practices and quantify the associations between herd management factors and bulk tank SCC in Irish, spring-calving, grass-based dairy herds.

ABSTRACT

The relationship between bulk tank somatic cell count (SCC) and farm management and infrastructure was examined using data from 398 randomly selected, yet representative, Irish dairy farms where the basal diet is grazed grass. Median bulk tank SCC for the farms was 282,887 cells/ml ranging from 82,209 to 773,028 cells/ml. Two questionnaires were administered through face-to-face contact with each farmer. Herd-level factors associated with bulk tank SCC were determined using linear models with annual somatic cell score (i.e., arithmetic mean of the natural logarithm of bulk tank SCC) included as the dependent variable. All herd

level factors were analysed individually in separate regression model, with included an adjustment for geographical location of the farm; a multiple regression model was subsequently developed. Management practices associated with low SCC included the use of dry cow therapy, participation in a milk recording scheme, and the use of teat disinfection post-milking. There was an association between low SCC and an increased level of hygiene and frequency of cleaning of the holding yard, passageways and cubicles. Herd management factors associated with bulk tank SCC in Irish grazing herds are generally in agreement with most previous studies from confinement systems of milk production.

Main points

- A representative random sample of 400 farms was surveyed, with two questionnaires administrated during a face-to-face interview with each farmer, between April and July 2006 ('summer') and between December 2006 and March 2007 ('winter'). Bulk tank milk samples were taken during the summer visit. Multiple regression models were developed using stepwise regression (SAS, 2006).
- There was considerable variation in the management practices conducted and the infrastructure (milk routine, hygiene, buildings) on dairy farms in Ireland. Some 96% of farms practiced dry cow therapy, 49% of farms were enrolled in a milk recording scheme, 37% wore gloves during milking, 43% had clean parlours and 48% of farms practiced no teat preparation before applying the cluster while 69% practiced disinfecting teat after every milking.
- Fifty percent of the 300 bulk tank milk samples taken tested positive for *Staphylococcus aureus*, and it was the only bacteria present. Thirty eight percent of samples had between 1 and 40 CFU while 12% of samples had greater than 40 CFU. There was a significant association between the level of *Staphylococcus aureus* (0, ≤40, >40 CFU) and bulk tank SCC; as the quantity of *Staphylococcus aureus* increased so did bulk tank SCC.
- Farm infrastructure associated with low bulk tank SCC included parlours which contained recorder jars, use of the milking jar to separate infected cow's milk, the presence of heated water in the parlour and the presence of cluster removers in the parlour.

- Farm hygiene had a large impact on bulk tank SCC; with a clean parlour, clusters, sheds, cubicles, yards and roadways all associated with low bulk tank SCC. A high frequency of cleaning the housing area and the use of paper or sawdust as bedding for cows during the housing period were also associated with low bulk tank SCC.
- Some management practices associated with low bulk tank SCC included participating in a milk-recording scheme, using a dry cow therapy program and practicing teat disinfection after every milking.

4. Farm Management Factors Associated with Bulk Tank Total Bacterial Count in Irish Dairy Herds during 2006/07

Objective: To quantify the associations between herd management factors and bulk tank total bacterial count (TBC) in Irish, spring calving, grass-based dairy herds.

ABSTRACT

Research has shown that total bacterial count (TBC) which is the bacterial growth per ml of milk over a fixed period of time can be decreased by good hygiene and farm management practices. The objective of the current study was to quantify the associations between herd management factors and bulk tank TBC in Irish, spring calving, grass-based dairy herds. The relationship between bulk tank TBC and farm management and infrastructure was examined using data from 400 randomly selected Irish dairy farms where the basal diet was grazed grass. Herd management factors associated with bulk tank TBC were identified using linear models with herd annual total bacterial score (i.e., arithmetic mean of the natural logarithm of bulk tank TBC) included as the dependent variable. All herd management factors were individually analysed in a separate regression model, which included an adjustment for geographical location of the farm. A multiple regression model was subsequently developed. Median bulk tank TBC for the sample herds was 18,483 cells/mL ranging from 10,441 to 130,458 cells/mL. Management practices associated with low TBC included the use of heated water in the milking parlour, participation in a milk

recording scheme and tail clipping of cows at a frequency greater than once per year. Increased level of hygiene of the parlour, cubicles and roadways was associated with lower TBC. Herd management factors associated with bulk tank TBC in Irish grazing herds were generally in agreement with most previous studies from confinement systems of milk production.

Main points

- A representative random sample of 400 farms was surveyed, with two questionnaires administrated during a face-to-face interview with each farmer, between April and July 2006 ('summer') and between December 2006 and March 2007 ('winter'). Multiple regression models were developed using stepwise regression (SAS, 2006).
- Farm infrastructure associated with low bulk tank TBC included a modern parlour design, six to eight units, a higher frequency of liner change and the presence of heated water in the parlour
- Farm hygiene had a large impact on bulk tank TBC; with clean parlour, clusters, sheds, cubicles, yards and roadway all associated with low bulk tank TBC. Using shredded paper or lime and mats as bedding for cows during the housing period was also associated with low bulk tank TBC.
- Some management practices associated with low bulk tank TBC included participating in a milk recoding scheme, a high frequency of tail hair clipping (cutting) and disinfecting teat after every milking.

5. Spatial Trends in Milk Somatic Cell Count in the Republic of Ireland from 2003 to 2007

Objective: 1) to describe the spatial distribution of herd SCC in milk-recording dairy herds throughout Ireland, 2) to examine if these SCC values were clustered, and 3) to determine the degree of change in the spatial pattern of SCC values over time.

ABSTRACT

Ireland produces approximately 5,157 million litres of milk annually which was estimated to be worth €1.4 billion to the Irish economy in 2007. However, milk somatic cell count (SCC) has increased in Ireland in recent years with adverse effects on economic returns both on- and post-farm. Mapping technology may assist in a multi-stranded national approach to tackling this issue, enabling policy-makers to identify geographical regions of high SCC, and facilitating the strategic allocation of finite resources, such as extension services. The objectives of this study were to describe the spatial distribution of herd SCC in milk-recording dairy herds throughout Ireland, to examine if these SCC values cluster, and to determine whether there has been a change in the spatial pattern of these SCC values over time. Herd-year geometric mean SCC values were available for 4,314 milk-recording herds during 2003 to 2007. Each herd was assigned an X and Y coordinate (location on map) based on the centroid of the largest farm fragment. A range of mapping and analysis tools were used including point and kernel density and clustering analysis methods. The south of the country had the greatest density of milk-recording herds. Approximately 60% of all herds in the study were from four counties (Cork, Kerry, Limerick and Tipperary). There was an increase in the average bulk tank SCC from 110,264 cells/mL in 2003 to 118,782 cells/mL in 2005, followed by a decrease to 108,454 cells/mL in 2007. Between 2006 and 2007 SCC decreased in the northeast, southeast and west of the country and an increased in the south. There was no spatial clustering of high SCC scores (i.e., SCC on one farm was not related to SCC on other farms), consistent with mastitis being a herd- as opposed to an area-based problem.

Main points

- Individual cow geometric mean SCC for herds present in each of the five years (2003-2007) of the study (21,695 herd-year records from 4,339 herds) were used for analysis. All analyses were conducted using ArcGIS v 9.3 (ESRI, Redlands, CA, USA).
- The density of milk recorded herds was greatest in the south of the country (66%), with densities in the northeast, southeast and west regions at 15, 15 and 4%, respectively.
- SCC increased and decreased over the years investigated. There was a general increase observed in 2004 compared to 2003. Milk SCC remained relatively

unchanged in most areas in 2005 and this was followed by a general decrease in 2006, and a decrease between 2006 and 2007 in all regions except in the southern area.

- There was significant clustering of milk-recording herds throughout Ireland.
- Clustering of SCC scores for 2003 to 2006 was not evident however in 2007 some clustering of SCC scores was detected. There were no high or low SCC scores clustered for any of the years. This indicated that the SCC scores that were clustered were in the medium SCC score range. Absence of clustering would have indicated that SCC was an individual herd problem.

6. The Relationship Between Somatic Cell Count and Parity, Stage of Lactation, Month of Calving and Age at Calving

Objective: To investigate how SCC differs across parity, stage of lactation, month of calving and age at calving centred within parity within a seasonal calving system where cows are at pasture for the main part of the year.

ABSTRACT

Grazed pasture constitutes the basal diet of dairy cows in Ireland, with 66% of dairy cows calving between February and April. There is a gap in the knowledge on the cow factors associated with SCC in a grass based production system. Thus, The objective of the current study was to investigate how SCC differs across parity, stage of lactation, month of calving and age at calving centred within parity within a seasonal calving system where cows are at pasture for the main part of the year. A total of 506,517 test day records from 740 milk recorded herds between 2002 and 2005 were used in this study. Differences in SCC among the factors under investigation were determined using mixed models with cow included as a random effect. The first 305 days post-calving were divided into ten stages of lactation in 30 day increments starting at 5 days in milk (DIM). SCC increased with parity from 97,000 cells/mL in parity 1 to 199,000 cell/mL in parity 6 which could be due to an

increased risk of infectious pathogens entering the udder and causing mastitis. SCC decreased between the period 5 to 35 DIM and 36 to 65 DIM, and increased thereafter. The rate of increase in SCS from mid to late lactation was greatest in older parity animals. Cows calving in the months of January and September had lower average SCC. The results from this study can be used in the development of strategies and decision support tools to help benchmark and predict SCC in grass based seasonal production systems.

Main points

- A total of 506,517 test day records from milk recorded herds between 2002 and 2005 were used in this study. Differences in SCC among the factors under investigation were determined using mixed models in ASReml (Gilmour, et al., 2007) with cow included as a random effect.
- Parity, stage of lactation and month of calving were all associated with SCC
- As the parity increased, so did the SCC. There was a decrease in SCC observed between the period of 5 to 35 DIM and the period 36 to 65 DIM, after which SCC increased until the end of lactation.
- The start of each calving period (month of calving) in spring and autumn (January and August respectively) was associated with lower SCC. The SCC increased as the month of calving advanced from January to July, decreased in August and September and increased again until the end of the year.
- As parity increased, the rate of increase in SCC between the period 36 to 65 DIM to the end of lactation also increased
- For cows calved in June and July, a levelling off or slight decrease in SCC was observed from the period 186 to 215 DIM until the end of lactation. For cows calved in April and May, a reduction in SCC was observed from the period 216 to 245 DIM until the end of lactation. In all other calving months SCC decreased between the period 5 to 35 DIM and 36 to 65 DIM, and increased thereafter until the end of lactation.

7. Association Between Milk Somatic Cell Count and Cow Milk Yield for Different Cow Parities in a Grass Based System

Objective: To examine both the association between SCC and milk yield across parities, accounting for stage of lactation and calving month as well as calculating SCC adjustments for individual parities on grass based dairy production systems.

ABSTRACT

Subclinical mastitis is one of the most costly diseases of dairy cattle. The cost of this problem may have been over-estimated in the past, as a consequence of the dilution effect of milk yield on somatic cell count (SCC). Some adjustment for the effect of dilution has recently been made, but without considering differences between parities. There are three objectives in the current study: 1) to investigate the association between SCC and milk yield within a seasonal grass based production system, 2) calculate the dilution estimates for each individual parity and 3) use these dilution estimates to investigate the dilution effect of milk yield on SCC. A total of 235,163 test day records from 23,791 cows in 366 Irish milk recorded herds between the years 2003 and 2005 were included in analysis. The association between SCC and milk yield was investigated using two models: 1) the association between both SCC and $\log_e$ SCC and milk yield was determined, and 2) four dilution estimates were used to adjust SCC to account for the dilution of SCC by milk yield. A negative association was observed between both SCC and $\log_e$ SCC and milk yield. When there was no pre-adjustment of SCC for milk yield, a test day milk loss of 1.43, 2.08, 2.59, 2.56 and 2.62 L was associated with an increase of SCC category from <51 to >400 in parity 1 to 5 animals, respectively. Additionally, two of the dilution estimates had similar trends in milk loss due to SCC to when there was no dilution estimate used. Alternatively, for the pre-adjustment of SCC that multiplied SCC by the mean test day milk yield as a proportion of the test day milk yield, there was an increase in test day milk yield with increasing SCC category. The results from this study can be used to more-accurately calculate the economic implications of SCC.

Main points

- Individual cow test day SCC for herds present in each of the three years (2003-2005) of the study (235,163 test day record from 23791 dairy cows (366 herds)) were used for analysis. The association of SCC and test day milk yield was estimated using linear mixed models (SAS) with test day milk yield as the dependent variable.
- Four models were used to investigate the influence of dilution on SCC (i.e. four adjustments of test day SCC) used for each parity (1.1 to 1.4), 1) no adjustment used, 2) adjusted SCC category = test day SCC/dilution estimate, 3) recorded SCC* (recorded test day milk yield/ mean test day milk yield for each parity), mean milk yield for parities 1 to 5 were 20.42, 23.34, 24.85, 25.34 and 25.33 respectively, 4) test day SCC + (-ß)(test day milk yield), a mixed model was developed for each parity SCC category of <50,000 cell/mL, as these animals were presumed uninfected; SCC was set as the dependent variable with the impact of herd, calving month and milk yield estimated, the regression coefficient for milk yield was calculated (ß) (-0.274, -0.442, -0.445, -0.520 and -0.441, regression coefficient (ß) for parities 1 to 5, respectively).
- The mean test day SCC was 229,014 cell/mL (175,084, 198,274, 242,300, 286,218 and 348,485 cells/mL, parities 1 to 5, respectively) and the mean test day milk yield was 23.2 litres (20.4, 23.3, 24.8, 25.3 and 25.3 litres, parities 1 to 5, respectively).
- There was a negative relationship between SCC and milk yield within parity. The milk loss associated log SCC for all parities (1 to 5) ranged between -3.47 and 0.56.
- The mean milk yield used to calculate the dilution estimate in the pre-adjustment of SCC that multiplied SCC by the mean milk yield as a proportion of the average calculated milk yield were 20.4, 23.3, 24.8, 25.3 and 25.3 litres, for parities 1 to 5, respectively. The dilution estimates in the current study changed the association between SCC and milk yield.

8. Implications

The research conducted in this study develops current knowledge on milk SCC in grass based dairy systems, from management and production perspectives. All the results from the study can be used for the development of management strategies to reduce the SCC and TBC at farm level (clean parlour, clusters, sheds, cubicles, yards and roadways, milk recoding scheme and disinfecting teat after every milking). The management strategies can be aided by the knowledge on the association between SCC and parity, stage of lactation and month of calving. The knowledge on stage of lactation can be used to predict high SCC farms earlier in the season as it was shown that SCC increases in late lactation. This allows intervention to prevent SCC increasing before an SCC problem arises. Results derived in the study make it possible to identify management practices to reduce SCC at herd level, e.g. a compact calving season and removal of late calving animals which were associated with high milk SCC. Limiting the number of older or high parity animals could also assist in reducing herd SCC. The association between milk yield and SCC increases the importance of management practices to reduce SCC within a herd, as the milk loss associated with SCC accounts for a not-insubstantial proportion of the herd's total milk yield. The results from the association between SCC and milk yield can be used to quantify the milk loss on grass based seasonal production systems. The dilution estimates in the study can also be used to help predict economic losses due to increased SCC adjusting for milk yield, for individual parties. The development of dilution estimates for all parities increases the accuracy of the estimated test day milk loss associated with SCC. The geographical mapping of the location and density of occurrence of average milk SCC could be used as a tool for the development and implementation of plans to reduce SCC in Irish dairy herds, such as allocating personnel where their expertise would be most beneficial. The tools could also be used to verify the uptake of advice and research and as an aid in detecting the relevance of advice and research to different areas (i.e. different soil types, temperature and rainfall around the country).

9. Further Research

There are a number of areas in which this research could be expanded and the data collected developed further. The knowledge on management practices associated with SCC and TBC could be expanded by observing the milking process on-farm; this would enable a milk management profile to be factored into analysis. Also, detailed information on milking machine operation would further develop knowledge on the association between SCC, TBC and milking practices. The study could be developed with additional knowledge on mastitis infection incidence and farm management procedures. Knowledge of mastitis incidence and the pathogens associated with infections on farms could be used to investigate the association between pathogen type and parity, month of calving, age at calving and stage of lactation on spring calving grass based dairy production systems. This information could also allow the study to be conducted on an infection free data set, which could potentially alter the association between SCC and parity, month of calving and stage of lactation.

Using the GIS methodology, it would be possible if farm practices where known to geographically map management practices which are associated with SCC; to investigate the uptake of knowledge and management practices around the country and associate that uptake with the SCC. It could also be possible to adjust SCC for differences in management practices. The use of bulk tank SCC for the country could expand the GIS mapping as there would be more data points which could lead to more accurate analysis, it could also cause an increase in the SCC around the country as milk recorded herds which were used in the current study have been reported (Hutton et al., 1990; Kelly et al., 2009) to be associated with lower SCC.

Data contained within this thesis could enable the development of an economic package to assess the cost of SCC on grass based production systems. Furthermore, information in chapters 2 and 3 could be used to calculate the cost benefit of practices such as teat spraying/dipping after milking. Data in chapter 5 could be used in conjunction with that in chapter 6 to estimate milk loss associated with SCC and determine the financial cost of different periods of lactation and parities within a herd. Finally, the tools used in chapter 4 could be used to geographically map the cost of SCC to the milk producers

10. Conclusions

The study includes various associations with milk SCC i.e. cow attributes, farm management practices, association with milk yield and geographical location and density of SCC. The study provides knowledge on the management practices and infrastructure for a representative sample of farms in Ireland, and emphasises the important relationships between herd management strategies and herd SCC and TBC. The management practices found to be associated with SCC in the current study were in agreement with those suggested in previous research except for factors such as parlour design, teat preparation and cow cleanliness. The difference in the cumulative effect between having the best practices to reduce milk SCC, such as use of dry cow therapy on all cows, having a clean parlour, heated water in the parlour, a recorder jar pipeline milking system and shredded paper for bedding cows, was calculated as 246,984 cells/ml compared to the poorest alternative in each variable. The difference in the cumulative effect between having the best practices to reduce milk TBC, such as participation in a milk recording scheme, heated water in the parlour, washing of the walkways before milking, maintaining the shed in good condition, tails clipped (cut) at a frequency of greater then once a year and clean cubicles, was calculated as 20,167 cells/mL compared to the poorest alternative in each variable. *Staphylococcus aureus* was the only pathogen present in the farm bulk tank milk samples taken during the spring survey, as the level of *S. aureus* increased in the bulk tank milk samples the level of SCC increased. The significant association between SCC and cow factors (parity, stage of lactation and month of calving) within the seasonal system investigated were similar to studies on non-seasonal systems. The rate of increase in SCS between the period 66 to 95 and the end of lactation increased with parity. The association found between milk yield and SCC was similar to that of other studies with a loss of 1.44, 2.08, 2.59, 2.56 and 2.62 litres (test day milk yield, parity 1 to 5 respectively) associated with a change in SCC category of <50 to >400. The geographical mapping of SCC of milk recorded herds did not show clustering of SCC, which indicates that SCC is a herd (as opposed to an area) problem. The GIS work also enabled a geographical profile of SCC and milk recording to be generated. The study increases the knowledge on SCC in grass based dairy production systems. Overall the work of the study emphasises the importance of SCC in a seasonal calving system and the management practices that aid in the decrease of the SCC problem in cow herds.

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