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The association between herd- and cow-level factors and somatic cell count of Irish dairy cows

S. McParland[1†], B. O'Brien[1] and J. McCarthy[2]
[1]*Livestock Systems Research Department, Animal and Grassland Research & Innovation Centre, Teagasc Moorepark, Fermoy, Co. Cork, Ireland*
[2]*Irish Cattle Breeding Federation, Bandon, Co. Cork, Ireland*

Somatic cell count (SCC) is an indicator of both udder health and milk quality and is measured at an animal level through national milk recording schemes. The objective of this study was to assess the animal and herd factors contributing to elevated SCC (i.e. poorer milk quality). Test day records (n = 2,658,928) from 519,456 cow lactations obtained between 2007 and 2011 were included in the analyses. Herd factors tested included the geographical region of the herd and production system operated (spring calving or mixed calving system). Animal factors tested included breed, parity and age nested within parity. Four definitions of normalised SCC (i.e. SCS) were considered: 1) average test-day SCS within a 24 hour period (TD_SCS), 2) maximum SCS (peak_SCS), 3) minimum SCS (min_SCS), and 4) average SCS (avg_SCS) recorded across cow lactation; in addition, the proportion of test day records with an SCC count >200,000 (prop_200) or >250,000 (prop_250) within cow lactation were included. Following adjustment for fixed effects, average TD_SCS was 179,308 cells per mL while avg_SCS, and average min_SCS and peak_SCS were 119,481, 50,992 and 298,813 cells per mL, respectively. All animal and herd factors had a significant effect on SCC. Older animals, animals which were younger at calving than contemporaries and Holstein animals had higher SCC than younger alternative breed animals who calved at the median age. In addition, mixed calving production systems and herds in Connaught had higher SCC than spring calving herds in the other regions of Ireland.

Keywords: animal factors; herd factors; somatic cell count, udder health

†Corresponding author: Sinead McParland, Tel: +353 25 42647; Fax: +353 25340;
E-mail: sinead.mcparland@teagasc.ie

Introduction

Milk quality encompasses milk composition, processability and bacterial status, and is of increasing importance to the Irish dairy industry as milk processors seek to add value to their products. Somatic cell count (SCC) refers to the quantity of leucocytes per mL of milk and is an indicator both of udder health, particularly mastitis (Mrode and Swanson 1996; Rupp and Boichard 1999; Koivula *et al.* 2005), and milk quality (Schukken *et al.* 1992; Hamann 2005).

Somatic cell count is influenced by many factors including age (Green *et al.* 2008), breed (Begley *et al.* 2009), stage of lactation and season (Olde Riekerink, Barkema and Stryhn 2007; Walsh *et al.* 2007). However, the effects of factors specific to the Irish production system on SCC are largely unknown. For example, due to its temperate climate, Ireland has a competitive advantage in producing grass, one of the cheapest forms of animal feed available (Dillon *et al.* 2005). Grazed grass forms up to 80% of the diet of the average Irish dairy cow (O'Donovan and Kennedy 2007). To optimise the proportion of grazed grass in the diet, the majority of Irish dairy herds operate a seasonal calving system whereby cows calve early in the springtime to synchronise the lactation curve with seasonal grass growth. However, climatic conditions (FAO 2008) and grass growth (Brereton 1995) differ according to the geographical region within Ireland and it is not known what effect these differences have on subsequent milk quality. In addition, although the Holstein-Friesian remains the dominant breed of dairy cow in Ireland, in recent years, alternative breeds including the Jersey, Montbelliarde and Norwegian Red have been recommended for use in Irish dairy herds and the Norwegian Red, in particular, has demonstrated improved health over Holstein-Friesians in Irish dairy herds (Begley *et al.* 2009).

The objective of this study was to identify animal and herd factors associated with somatic cell count in lactating Irish dairy cows. Animal factors assessed included the parity, age at calving, stage of lactation and breed fraction of the cow. The herd factors tested included the geographical location of the herd and herd system of production.

Materials and Methods

Data

Milk recording data on 58,659,604 test day records from 2,789,000 individual cows across 8,669,464 lactations were obtained from Irish Cattle Breeding Federation national database. Corresponding information on fixed effects of animals including ancestry, breed fractions, date of birth, parity, herd identifier as well as herd information including region of location were also obtained from the national database. On average animals had 21.0 test day records across their lifetime, or 6.8 test day records per lactation.

Data edits

Data were categorised into spring calving and mixed season calving herds. Mixed season calving herds were defined as herds where for any given calendar year, at least 20% of the cows calved between the 30th June and the 15th December. Otherwise, herds were classed as spring calving herds. Geographical location of herds was classified according to the region (Ulster, Leinster, Munster and Connaught) of the milk recording herd. Contemporary group of herd-year-season of calving was defined according to the Crump algorithm and herd-year-seasons with <5 records were removed from the analyses. Where an animal moved herd during lactation, the records for that animal lactation were removed from the analyses.

A univariate analysis of age at calving within parity was performed and extreme age at calving records were defined as those in the 1% and 99% quartiles and were removed from the analyses. Subsequently, age at calving was defined as a class variable with three classes where animals were, 1) younger than 1 SD from the median age at calving, 2) median age at calving +/- 1 SD and 3) older than 1 SD from the median age at calving. Test day records from animals greater than tenth parity were removed from the data set; parities greater than four were grouped for the analyses. Only records from days 5 to 305 of lactation were retained and stage of lactation was defined with 10 classes in 30 day intervals.

The coefficient of heterosis and the coefficient of recombination loss were calculated for each animal as:

$$1-\sum_{i=1}^{n} sire_i \cdot dam_i$$ (VanRaden 1992)

and

$$1-\sum_{i=1}^{n} \frac{sire_i^2 + dam_i^2}{2}$$ (VanRaden and Sanders 2003)

respectively, where $sire_i$ and dam_i are the proportion of breed i in the sire and dam, respectively.

Records obtained between 2007 and 2011 from Holstein, Friesian, Jersey, Montbelliarde and Norwegian Red animals were retained. Animals were categorised according to breed and were assigned to a population if a minimum of 75% of their breed fraction was from that population. A random sample of 25% of herds was retained from analysis. The final data set comprised 2,658,928 test day records for analysis from 519,456 cow lactations.

Trait definition

Somatic cell count was normalised to somatic cell score (SCS) using the transformation: SCS = $\log_{10}$ (SCC*1000).

The average test-day SCS within a 24 hour period was obtained (TD_SCS) and three additional SCS traits were defined: the maximum SCS recorded per cow lactation (peak_SCS), the minimum SCS recorded per cow lactation (min_SCS), and the average SCS recorded across cow lactation (avg_SCS). In addition, the proportion of test day records within cow lactation with an SCC count greater than 200,000 (prop_200) and with an SCC count >250,000 (prop_250) were recorded.

Data analysis

All dependent variables were analysed using a repeatability model in ASReml (Gilmour *et al.* 2006) and predicted values of dependent linear variables and of each level of the dependent class variables, weighted by class size, were obtained using the following model:

Y ~ μ + age + province + herd_type + parity + heterosis + recombination + main breed (+ stage + test month) + animal + hys_calv (+ perm_lact);

where Y was the dependent variable (TD_SCS, min_SCS, peak_SCS, avg_SCS, prop_200 or prop_250), fixed effects accounted for included age at calving nested within parity (n = 3), province which represented the herd region (n = 4: Ulster, Munster, Leinster and Connaught), herd type which represented the calving system operated (n = 2: spring or mixed season calving), parity (n = 5), main breed of the animal (n = 5: Holstein, Friesian, Jersey, Montbelliarde, and Norwegian Red) and the heterosis and recombination effects of the animal. The random effects of animal and herd-year-season of calving

(HYS_calv) were included in all models. When the dependent variable was TD_SCS, additional fixed effects included stage of lactation (n = 10) and test month (n = 12) and the random permanent environment of the animal within lactation (perm_lact) was also included.

Results and Discussion

Of the herds used in the analyses, 79% were classified as spring calving herds, whilst 67%, 24%, 5% and 4% of herds were located in the Munster, Leinster, Ulster and Connaught provinces, respectively. Parity groups were evenly represented with 25%, 21%, 17%, 13% and 24% of animals in first to parity 5+. Animals had between four and twelve test-days per parity. The data set comprised records from 94.4% Holstein, 4.0% Friesian, 0.8% Montbelliarde, 0.2% Norwegian Red, and 0.6% Jersey animals.

Unadjusted mean and median SCC across the data set were 279,339 and 104,000 cells per mL, respectively. All results are presented from this point onwards as SCC back transformed from SCS (i.e. geometric averages), unless otherwise stated. Following adjustment for fixed effects, average TD_SCS was 179,308 cells per mL while the lactation average (avg_SCS) was 119,481, and average min_SCS, peak_SCS, prop_200 and prop_250 were 50,992 cells per mL, 298,813 cells per mL, 30% and 24%, respectively.

Animal factors associated with SCS

All animal factors tested had a significant effect on SCS. Test day SCS was lowest in first parity animals and increased with parity (P<0.001) from 139,894 cells per mL in first parity animals to 266,993 cells per mL in parity 5+ animals (Table 1). Similarly, lactation average (avg_SCS) and peak_SCS were lowest in first parity animals and increased with parity (P<0.001), however, the lowest lactation minimum (min_SCS; 42,462 cells per mL) was observed in second parity cows. The proportion of records >200,000 and 250,000 ranged, respectively, from 19.8% to 43.9% and from 15.1% to 37.2% for first to fifth parity animals. The effect of age on SCC observed in this study is consistent with other populations (Laevens *et al.* 1997; Walsh *et al.* 2007; Green *et al.* 2008) and is likely linked to the increased exposure to infection as animals remain in herds.

Animals which were the median age at calving (within parity) had the lowest TD_SCS, avg_SCS, peak_SCS and min_SCS while animals that calved at a younger age (>1 SD younger than the median age at calving within parity) had the highest TD_SCS, avg_SCS, min_SCS and peak_SCS (Table 1). Animals that calved younger also had 6.9% and 6.3% higher prop_200 and prop_250 records, respectively (P<0.001), relative to contemporaries who were at the median age at calving. This suggests that animals that calve at an early age may have compromised immunity as energy resources are still focussed on growth. Nyman *et al.* (2008) demonstrated the different metabolite and immune variable profiles of heifers that calved at different ages. Higher levels of serum β-hydroxybutyrate and glucose or lower levels of nonesterified fatty acids pre-calving were associated with lower SCC at the first test-milking. However, no strong conclusions were drawn in that study regarding the effect of age at calving on subsequent SCC. In this study, animals that calved at an older age than those that calved at the median age at calving had higher SCC (Table 1). Animals that calve at an older age compared to contemporaries will have been exposed to mastitis causing pathogens in the herd

Table 1. Animal and herd factors influencing somatic cell count[1]

	Test day		Lactation average		Lactation peak		Lactation minimum	
	SCS(SCC)[2]	SE	SCS(SCC)	SE	SCS(SCC)	SE	SCS(SCC)	SE
Breed								
Holstein	5.25(179,432)[a]	0.001	5.08(119,564)[a]	0.001	5.48(299,778)[a]	0.001	4.71(51,074)[a]	0.001
Friesian	5.24(175,186)[b]	0.013	5.07(116,574)[b]	0.013	5.47(292,012)[b]	0.016	4.69(49,125)[b]	0.014
Montbelliarde	5.15(141,124)[c]	0.004	4.98(94,842)[c]	0.004	5.40(248,828)[c]	0.005	4.60(39,555)[c]	0.004
Jersey	5.22(164,816)[b]	0.009	5.04(109,547)[b]	0.009	5.46(289,135)[ab]	0.011	4.66(45,983)[b]	0.010
Norwegian Red	5.14(139,412)[c]	0.015	4.97(93,951)[c]	0.015	5.37(232,648)[c]	0.018	4.61(41,115)[c]	0.015
Age at calving								
Class 1	5.35(222,485)[a]	0.016	5.16(145,680)[a]	0.017	5.55(355,059)[a]	0.021	4.79(61,901)[a]	0.018
Class 2	5.24(174,221)[b]	0.001	5.07(116,225)[b]	0.001	5.46(289,468)[b]	0.001	4.70(49,808)[b]	0.001
Class 3	5.29(193,999)[c]	0.001	5.11(128,914)[c]	0.002	5.51(326,062)[a]	0.002	4.74(54,413)[c]	0.002
Parity								
1	5.15(139,894)[a]	0.001	4.98(94,558)[a]	0.001	5.34(218,172)[a]	0.002	4.66(45,730)[a]	0.002
2	5.16(143,087)[b]	0.001	4.99(96,605)[b]	0.001	5.37(233,615)[b]	0.002	4.63(42,462)[b]	0.002
3	5.23(169,707)[c]	0.001	5.05(113,397)[c]	0.002	5.46(287,012)[c]	0.002	4.67(46,871)[c]	0.002
4	5.30(201,280)[d]	0.001	5.12(133,229)[d]	0.002	5.54(348,658)[d]	0.002	4.73(53,543)[d]	0.002
5	5.43(266,993)[e]	0.001	5.24(173,860)[e]	0.001	5.67(468,274)[e]	0.002	4.83(67,686)[e]	0.001
Province								
Munster	5.27(184,757)[a]	0.001	5.09(122,744)[a]	0.001	5.47(295,801)[a]	0.002	4.74(55,578)[a]	4.683
Ulster	5.21(163,983)[b]	0.004	5.05(111,712)[b]	0.004	5.47(294,239)[a]	0.006	4.67(42,609)[b]	4.705
Leinster	5.22(166,265)[b]	0.002	5.05(111,148)[b]	0.002	5.48(302,204)[b]	0.003	4.64(41,668)[b]	4.683
Connaught	5.29(193,553)[c]	0.004	5.11(129,778)[c]	0.005	5.53(340,408)[c]	0.006	4.72(52,036)[c]	4.705
Herd type								
Mixed calving	5.11(127,350)[a]	0.002	5.10(125,806)[a]	0.002	5.55(350,752)[a]	0.003	4.69(48,989)[a]	0.003
Spring calving	5.09(123,794)[b]	0.001	5.06(114,948)[b]	0.001	5.44(277,077)[b]	0.001	4.70(50,594)[b]	0.001

[1]Superscript letters indicate statistical significance ($P<0.05$). Values with the same letter within a column are not statistically different.
[2]SCS represents somatic cell score with back transformed somatic cell count (SCC) in parentheses.

for longer. Despite this, De Vliegher *et al.* (2004) found that heifers that were older at calving had lower SCC, however that study was undertaken at a herd level, thus the dilution effect could not be accounted for.

Across all SCS traits studied, Holstein animals had the highest SCS (179,432 TD_SCS per mL), and while the Norwegian Red had numerically the lowest SCS across all breeds (139,412 TD_SCC per mL), there was no significant difference ($P>0.05$) between Norwegian Red and Montbelliarde animals (141,124 TD_SCC per mL; Table 1). Mean differences amongst breeds for avg_SCC ranged from 25,613 TD_SCC cells per mL between Holsteins and Norwegian Reds to 2,990 cells per mL between Holsteins and Friesians. Holsteins had the greatest prop_250 (24%) whilst Montbelliardes and Norwegian Reds had the lowest (19%; $P<0.001$). The proportion of both of Norwegian Red and Montbelliarde represented in this dataset were very small making it difficult to detect statistical differences between groups. However, the lack of difference between Norwegian Red and Montbelliarde animals is consistent with the findings of Walsh *et al.* (2007)

who investigated breed differences in an Irish research herd. In addition, those authors also found the SCS of Norwegian Red and Montbelliarde animals to be lower to other breeds investigated in that study, the Holstein-Friesian, Normande and crossbred animals.

An elevated TD_SCS was observed during days 5 to 30 of lactation relative to days 30 to 60 as SCC dropped from 100,670 cells per mL to 85,842 cells per mL. Subsequently, SCC rose until the end of lactation (P<0.001). The trend of elevated SCC immediately after calving, followed by a reduction and subsequent rise in SCC toward the end of lactation is common across populations (Laevens *et al.* 1997; Walsh *et al.* 2007; Hagnestam-Nielsen *et al.* 2009) and supports the theory that SCC can be diluted with increasing milk yield (Wicks and Leaver 2006).

TD_SCS was highest in the winter months with a peak of 206,063 cells per mL in November and dropped to a low of 163,493 cells per mL in May (Figure 1). It is typical for animals to be housed indoors during the winter months in Ireland but to be kept outdoors from February through to October. The deleterious effect of housing relative to alternative grazing systems on SCC has been well documented (Goldberg *et al.* 1992).

Herd factors associated with SCS

Both system of production and geographical region (province) had a significant effect on TD_SCS, avg_SCS, peak_SCS, min_SCS, prop_200 and prop_250. Spring calving herds had lower TD_SCS, avg_SCS, peak_SCS, prop_200 and prop_250 relative to mixed calving herds although the difference between spring and mixed calving herds tended to be small (Table 1). Connaught had the highest TD_SCS, avg_SCS, peak_SCS, prop_200 and prop_250 while herds in Ulster had the lowest TD_SCS and peak_SCS; Munster herds had the lowest prop_250 (P<0.05). Differences in prevailing climatic conditions across Ireland, including differences in air temperature, soil temperature, annual rainfall and hours of sunshine (FAO 2008) lead to different herd management and housing conditions (Fitzgerald, Brereton and Holden 2005) which are known to affect SCC. Fitzgerald *et al.* (2005) developed a simulation tool designed to quantify the associations between climate and management in Irish spring producing dairy herds. The simulation tool was subsequently tested on three sites across Ireland representing the south, west and east of Ireland. To achieve optimal production, the sites in the south and west, i.e. Munster and Connaught required the longest periods of housing (Fitzgerald *et al.* 2005) which was

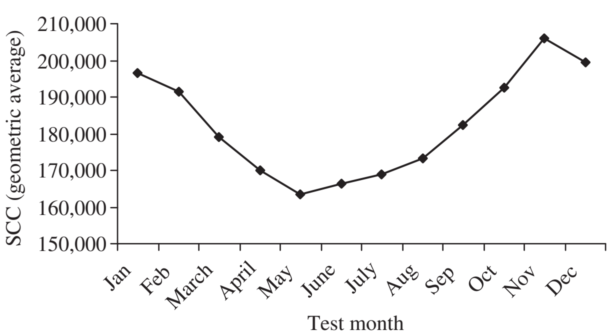

Figure 1. Test month effects on test day somatic cell count (SCC).

associated with increased levels of SCC (Goldberg *et al.* 1992).

Conclusion

All animal and herd factors tested had a significant effect on SCC. Older animals, animals that were younger at calving than contemporaries and Holstein animals had higher SCC than younger alternative breed animals that calved at the median age. In addition, mixed calving production systems and herds in Connaught had higher SCC than spring calving herds in the other regions of Ireland.

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References

Begley, N., Buckley, F., Pierce, K.M., Fahey, A.G. and Mallard, B.A. 2009. Differences in udder health and immune response traits of Holstein-Friesians, Norwegian Reds, and their crosses in second lactation. *Journal of Dairy Science* **92**: 749–757.

Brereton, A.J. 1995. Regional and year to year variation in production. In: "Irish Grasslands – their Biology and Management" (eds. D.W. Jeffrey, M.B. Jones and J.H. McAdam), Royal Irish Academy, Dublin, Ireland, pages 12–22.

De Vliegher, S., Laevens, H., Barkema, H.W., Dohoo, I.R., Stryhn, H., Opsomer, G. and de Kruif, A. 2004. Management practices and heifer characteristics associated with early lactation somatic cell count of Belgian dairy heifers. *Journal of Dairy Science* **87**: 937–947.

Dillon, P., Roche, J.R., Shalloo, L. and Horan, B. 2005. Optimising financial return from grazing in temperate pastures. In: "Utilization of Grazed Grass in Temperate Animal Systems". *Proceedings of a Satellite Workshop of the XXth International Grassland Congress*, *Cork, Ireland* (ed. J.J. Murphy), Wageningen Academic Publishers, The Netherlands, pages 131–148.

Food and Agriculture Organization of the United Nations (FAO). 2008. Country Forage /Pasture Resource Profiles - Ireland. Available online: www.fao.org/ag/agp/AGPC/doc/Counprof/Ireland/Ireland.htm#climate. [accessed 15 October 2013].

Fitzgerald, J.B., Brereton, A.J. and Holden, N.M. 2005. Assessment of regional variation in climate on the management of dairy cow systems in Ireland using a simulation model. *Grass and Forage Science* **60**: 283–296.

Gilmour, A.R., Gogel, B.J., Cullis, B.R. and Thompson, R. 2006. ASReml, Release 2.0, VSN International Ltd, Hemel Hempstead, UK.

Goldberg, J.J., Wildman, E.E., Pankey, J.W., Kunkel, J.R., Howard, D.B. and Murphy, B.M. 1992. The influence of intensively managed rotational grazing, traditional continuous grazing, and confinement housing on bulk tank milk quality and udder health. *Journal of Dairy Science* **75**: 96–104.

Green, M.J., Bradley, A.J., Medley, G.F. and Browne, W.J. 2008. Cow, farm, and herd management factors in the dry period associated with raised somatic cell counts in early lactation. *Journal of Dairy Science* **91**: 1403–1415.

Hagnestam-Nielsen, C., Emanuelson, U., Berglund, B. and Strandberg, E. 2009. Relationship between somatic cell count and milk yield in different stages of lactation. *Journal of Dairy Science* **92**: 3124–3133.

Hamann, J. 2005. Diagnosis of mastitis and indicators of milk quality. In: "Mastitis in Dairy Cow Production. Current Knowledge and Future Solutions" (ed. H. Hogeveen), Wageningen Academic Publishers, The Netherlands, pages 82–90.

Koivula, M., Mantysaari, E.A., Negussie, E. and Serenius, T. 2005. Genetic and phenotypic relationships among milk yield and somatic cell count before and after clinical mastitis. *Journal of Dairy Science* **88:** 827–833.

Laevens, H., Deluyker, H., Schukken, Y.H., De Meulemeester, L., Vandermeersch, R., De Mue Lenaere, E. and De Kruif, A. 1997. Influence of parity and stage of lactation on the somatic cell count in bacteriologically negative dairy cows. *Journal of Dairy Science* **80:** 3219–3226.

Mrode, R.A. and Swanson, G.J.T. 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. *Animal Breeding* **64**: 847–857.

Nyman, A.K., Emanuelson, U., Holtenius, K., Ingvartsen, K.L., Larsen, T. and Persson Waller K. 2008. Metabolites and immune variables associated with somatic cell counts of primiparous dairy cows. *Journal of Dairy Science* **91:** 2996–3009.

Olde Riekerink, R.G.M., Barkema, H.W. and Stryhn, H. 2007. The effect of season on somatic cell count and the incidence of clinical mastitis. *Journal of Dairy Science* **90:** 1704–1715.

O'Donovan, M. and Kennedy, E. 2007. Using grass to reduce feed costs. In: "Exploiting the Freedom to Milk". *Proceedings of Teagasc National Dairy Conference,* Teagasc, Carlow, Ireland, pages 63–80. Available online: www.teagasc.ie/publications/view_publication.aspx?PublicationID=53 [accessed 3 December 2013].

Rupp, R. and Boichard, D. 1999. Genetic parameters for clinical mastitis, somatic cell score, production, udder type traits, and milking ease in first lactation Holsteins. *Journal of Dairy Science* **82:** 2198–2204.

Schukken, Y.H., Leslie, K.E., Weersink, A.J. and Martin, S.W. 1992. Ontario bulk milk somatic cell count reduction program. 1. Impact on somatic cell counts and milk quality. *Journal of Dairy Science* **75:** 3352–3358.

VanRaden, P.M. 1992. Accounting for inbreeding and crossbreeding in genetic evaluation of large populations. *Journal of Dairy Science* **75**: 3136–3144.

VanRaden, P.M. and Sanders, A.H. 2003. Economic merit of crossbred and purebred dairy cattle. *Journal of Dairy Science* **86**: 1036–1044.

Walsh, S., Buckley, F., Berry, D.P., Rath, M., Pierce, K., Byrne, N. and Dillon, P. 2007. Effects of breed, feeding system, and parity on udder health and milking characteristics. *Journal of Dairy Science* **90:** 5767–5779.

Wicks, H.C.F. and Leaver, J.D. 2006. Influence of genetic merit and environment on somatic cell counts of Holstein-Friesian cows. *Veterinary Journal* **172**: 52–57.

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