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Examining the impact of mastitis on the profitability of the Irish dairy industry

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Mastitis was identified as a priority disease within the Irish dairy industry by both dairy farmers and industry animal health experts, which led to the development of the CellCheck programme. In order to support this programme it was necessary to understand the extent to which mastitis affects farm profit, processor returns and ultimately industry profitability. To this end, an analysis of the impact of mastitis on farm, processor and the overall industry profitability was carried out. The impact of mastitis on farm costs, farm receipts and farm profitability is presented across a range of bulk milk somatic cell count (SCC) categories from <100,000 to >400,000 cells/mL. A meta-analysis of the relationship between SCC and raw milk composition, cheese processing characteristics and cheese composition was carried out and utilised to establish the impact of mastitis on processor returns. As SCC increased, the impact of mastitis on the volume of product that could be produced, net processor returns, milk price and the values per kg of fat and protein were calculated. The farm and processor analysis were then combined to estimate the impact of mastitis on the Irish dairy industry returns, accounting for both farm and processor costs. The analysis suggests that as cell count reduced from >400,000 to <100,000 cells/mL, overall returns to the farm should increase by 4.8 c/L, including the farm and processor related effects. Nationally, if the cell count was reduced by 10%, it would be worth €37.6 million for the Irish dairy industry.

Keywords: costs; dairy industry; economics; mastitis; somatic cell count

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Introduction

Berry *et al*. (2006) documented the temporal trends in bulk milk tank somatic cell counts (BMSCC) in Irish dairy herds from 1994 to 2004. That analysis showed that between 2000 and 2004 there was an annual increase in SCC of 2,000 cells/mL in BMSCC, resulting in a national geometric mean of 250,937 cells/mL in 2004. Recent estimates based on 2011 data suggest that the national average BMSCC has increased (Teagasc 2012). This upward trend in the national BMSCC has negative implications at farm, processor and industry level in terms of suppressed milk production, higher culling rates, higher on-farm costs, lower product yields and lower product quality, all of which ultimately have a negative impact on farm, processor and industry profit.

In 2009, dairy farmers and industry animal health experts identified udder health and milk quality as a priority animal health issue on Irish dairy farms (More *et al*. 2010). This led to the development of the CellCheck programme. However, in order for this programme to address the issues, it was necessary to quantify the current cost of mastitis to the Irish dairy industry. This would indicate the motivation required for farmers and processors to acknowledge the scale of the problem and thus implement effective management practices. To address this data gap, research was conducted on the impact of mastitis on farm profitability, processor profitability, value of milk and overall profitability of the Irish dairy industry. The purpose of this article is to provide a single source which succinctly summarises this research, which has numerous applications for the Irish dairy industry.

Farm Profitability and Mastitis

The analysis carried out by Geary *et al*. (2012a) to examine the impact of mastitis on farm profitability followed similar methodologies to the international research in the area (Bar *et al*. 2008; Huijps, Lam and Hogeveen 2008; Hagnestam-Nielsen and Ostergaard 2009). To carry out this analysis, data on the farm specific costs of mastitis on Irish dairy farms were collated and incorporated into the Moorepark Dairy Systems Model (MDSM) (Shalloo *et al*. 2004). The MDSM then calculated total farm costs, total farm receipts, net farm profit and the margin per litre for a 40 hectare farm. Five distinct BMSCC categories were examined in the analysis; ≤100,000, 100,001–200,000, 200,001–300,000, 300,001–400,000 and >400,000 cells/mL.

Moorepark dairy systems model

The MDSM (Shalloo *et al.* 2004) is a stochastic budgetary simulation model of a typical Irish dairy farm. It allows investigation of the effects of varying biological, technical, and physical processes on farm profitability. The model integrates animal inventory, milk production, feed requirements, land and labour utilisation, to provide an economic analysis of the production system. The outputs of the MDSM include financial indicators (cash flow, profit and loss and balance sheet) and physical outputs (feed budget, nutrient balance sheet and physical ratios). For each BMSCC category, total farm receipts (milk and livestock receipts), total farm costs (variable and fixed costs and depreciation), and net farm profit (total farm receipts – total farm costs) were calculated. A thorough description of the MDSM model and the incorporated mastitis components is available in Shalloo *et al*. (2004) and Geary *et al*. (2012b).

Farm specific costs of mastitis

Data on the Irish farm specific costs of mastitis were taken from a number of sources including Kelly (2009), the Irish Cattle Breeding Federation (ICBF 2010) milk recording database, survey data collected from the Herd Ahead Programme (Sayers 2009) and a Mastitis Farm Practice survey administered to a sample of the Herd Ahead farmers (full detailed description available in Geary *et al*. 2012a).

Reduced milk production

Kelly (2009) examined the relationship between SCC and milk yield across parities, accounting for stage of lactation and calving month. Using the ICBF milk recording data, Kelly (2009) estimated the average milk losses per day across the lactation for parity 1 to 5 cows across each of the 5 BMSCC categories. This data was coupled with the average parity structure of Irish dairy farms for each BMSCC category which was based on ICBF data. The estimated volume of reduced milk production per cow over the length of the lactation for each BMSCC category is presented in Table 1. The price per litre of unrealised milk was assumed at 27 cents per litre (Binfield *et al.* 2008).

Diagnostic testing

Information on the mastitis diagnostic testing practices on Irish dairy farms were collected from the Mastitis Farm Practice Survey and coupled with the ICBF data to capture the testing practices by BMSCC category. Table 1 summarises the proportion of farms carrying out bulk tank and individual cow milk culture analysis. A cost per milk culture of €5.05 was assumed in the analysis (Department of Agriculture, Food and the Marine 2011).

Cases treated

The number of subclinical cases treated was identified from the Mastitis Farm Practice Survey and coupled with herd size and BMSCC data from the ICBF database to calculate the proportion of the herd treated for subclinical mastitis across the five BMSCC categories. The number of clinical mastitis cases treated was calculated in a similar way but was obtained from the Herd Ahead Programme (Sayers 2009). Generally, as BMSCC increased the proportion of the herd treated for clinical mastitis increased. Table 1 summarises the clinical and subclinical mastitis treatment practices and rates for each BMSCC category.

Treatment and veterinary attention

Data on mastitis treatment procedures on Irish dairy farms were obtained from the Mastitis Farm Practice Survey; the proportion of cases of mastitis (clinical or subclinical) treated with (i) intramammary tubes only, (ii) injectable antibiotics only, (iii) a combination of both and (iv) pain relief were included in the analysis. The costs of injectable antibiotics were weighted by severity: mild cases incurred the cost of intramuscular antibiotics while severe cases incurred the cost of intravenous antibiotics and veterinary attention. The assumed cost per treatment with intramammary tubes was €9.90, with injectable antibiotic (weighted by severity) was €21.26 and pain relief administered was €16.50.

Discarded milk

Milk from mastitic cows treated with antibiotics was assumed to be withheld from the tank for 5 days (3 days treatment, 2 days post treatment) to avoid antibiotic residues in the milk supplied to processors. High SCC milk or antibiotic residue milk is fed to calves on the majority of farms (Mastitis Farm Practice Survey), however, this is only feasible while the calves are available to consume the milk. Therefore, it was assumed in the MDSM that all discarded milk was fed to calves

Table 1. On-farm mastitis treatment practice assumptions across bulk milk somatic cell count categories

	Somatic cell count categories ('000 cells/mL)					Significance
	<100 (Baseline)	100–200	200–300	300–400	>400[1]	
Milk production loss (L/lactation length)[2]	177	351	485	544	601	
Proportion of farms carrying out bulk tank milk cultures (%)[3]	1	2	1	1	1[4]	
Proportion of farms carrying out individual milk cultures (%)[3]	1	3	1	4	8[4]	
Proportion of clinical cases treated (%)[4]	11[a]	15[ab]	21[bc]	29[c]	38	**
Proportion of sub-clinical cases treated (%)[3]	1	1	4	2	1[4]	
Proportion of cases treated using intra-mammary tubes only (%)[3]	59	90	73	55	37[4]	
Proportion of cases treated using injectable antibiotics only (%)[3]	5[a]	1[a]	6[a]	19[b]	32[4]	*
Proportion of cases treated using both (%)[3]	37	9	21	26	31[4]	
Proportion of cases treated using pain relief (%)[3]	21	21	18	13	7[4]	
Proportion of farms discarding milk (%)[3]	12[a]	17[ab]	24[bc]	32[c]	39[4]	**
Proportion of herd culled due to mastitis (%)[3]	3[a]	5[a]	9[ab]	11[b]	13[4]	**

[a–c]Means within a row with different superscripts differ.

[1]Assumptions for the >400,000 cells/mL category were extrapolated from the difference between 200,000-300,000 cells/mL and 300,000-400,000 cells/mL categories.

[2]Source: Kelly (2009).

[3]Source: Mastitis Farm Practice Survey.

[4]Source: Herd Ahead Survey (Sayers 2009).

between January and May until calves were weaned; thereafter, the milk was discarded. The proportion of farms discarding milk across each BMSCC threshold is summarised in Table 1 and is based on the clinical and subclinical cases treated.

Culling

The proportion of the herd culled due to mastitis was estimated from the Mastitis Farm Practice Survey in conjunction with ICBF data. As SCC increased, the proportion of the herd culled due to mastitis increased from 3% at a BMSCC <100,000 cells/mL to 13% at a BMSCC of >400,000 cells/mL (Table 1). The value of a culled cow was assumed at €400, while the cost of a replacement heifer was assumed at €1,451 (Geary *et al.* 2012a).

The seasonality of SCC was accounted for in the analysis by applying a weighting to the monthly SCC in the MDSM. This was done by utilising data from Berry *et al*. (2006) which documented the monthly trend in geometric mean SCC using Irish data. The biological and cost data, for each of the BMSCC categories, were incorporated into the MDSM model to estimate the effect that mastitis costs have on the profitability of a 40 hectare farm (holding land area constant).

Farm Results

Physical results

As BMSCC increased the volume of milk delivered decreased, the replacement rate increased and milk solids per cow decreased for an average 40 hectare farm (Table 2). The decrease in milk delivered reflected the reduced milk production as BMSCC increased as well as replacing multiparous cows with primiparous cows. The replacement rate increased from 19% at <100,000 cells/mL at a cost of €25,550 to 28% at >400,000 cells/mL at a cost of €40,709.

Financial results

Total farm receipts decreased as BMSCC increased, which incorporated the reduced milk returns and increased livestock receipts from cull cows as BMSCC

Table 2. Impact of mastitis on the physical and financial outputs of a typical 40 hectare Irish dairy farm across 5 bulk milk somatic cell count categories

Model outputs		Somatic cell count categories ('000)				
		<100 (Baseline)	100–200	200–300	300–400	>400[1]
Physical outputs	Cows calving	94	96	99	100	101
	Milk delivered (kg)	532,122	524,614	518,834	516,198	513,596
	Replacement rate (%)	19	20	24	26	28
	Kg MS[2](kg)	37,530	36,995	36,573	36,380	36,190
	MS[2] per cow (kg)	411	397	382	376	370
Financial outputs	Total farm receipts (€)	192,147	191,617	192,342	190,431	189,091
	Total farm receipts (cents/kg)	36.1	36.5	37.1	36.9	36.8
	Total farm costs (€)	161,085	164,994	172,749	173,536	177,343
	Total farm costs (cents/kg)	30.3	31.5	33.3	33.6	34.5
	Net farm profit (€)	31,252	26,771	19,661	16,936	11,748
	Net farm profit/kg (cents/kg)	5.9	5.1	3.8	3.3	2.3

[1]The outputs for the >400,000 cells/mL BMSCC category were based on extrapolated assumptions using the data from the 200,000-300,000 cells/mL and the 300,000-400,000 cells/mL categories.
[2]Milk solids.

increased (Table 2). Total farm costs increased as BMSCC increased, which reflected the increased costs of treating mastitis cases on the farm and the increased cost of purchasing/rearing replacement heifers. Overall the net farm profit decreased by €19,504 (from €31,252 to €11,748) for a 40 hectare farm, as BMSCC increased from <100,000 cells/mL to >400,000 cells/mL.

Processor Profitability and Mastitis

Estimating the impact of mastitis at processor level, in terms of production and revenue, relative to the farm analysis has not been examined to the same extent in the international literature. To carry out this analysis the relationship between BMSCC and (i) raw milk composition, (ii) cheese processing characteristics and (iii) cheese composition needed to be elucidated. Due to the variability in the literature on the relationship between BMSCC and raw milk and cheese, a meta-analysis was carried out.

Meta-analysis

Meta-analysis allows the results of many studies to be combined, consequently the pooled dataset has greater power than individual studies to detect small but significant effects and gives more precise estimates of the size of the effects (Crombie and Davies 2009; St-Pierre 2001). To carry out the meta-analysis the literature was reviewed and two databases were developed; the first pooled data from 32 scientific articles on the relationship between SCC and raw milk composition, the second pooled data from 13 scientific articles on the relationship between SCC and cheese processing and cheese composition. As SCC increased, changes in (1) milk composition and (2) cheese processing and composition were analysed with random regression models using the MIXED procedure in SAS 9.3 (SAS 2010).

The analysis showed that as SCC increased the crude protein, true protein, non protein nitrogen, total nitrogen, whey protein and fat content of milk significantly increased (Table 3). As SCC increased, the lactose and casein as a percentage of true protein content of milk significantly decreased. Fat and protein recovery during processing was significantly decreased (Table 3). The moisture content of cheese was found to increase significantly as SCC increased while the protein content of cheese decreased significantly (Table 3).

The results of the meta-analysis highlighted that increased SCC was associated

Table 3. Significant relationships between somatic cell score and raw milk composition, cheese processing and cheese composition[1]

	Intercept	SE	P-value	Slope	SE	P-value
Raw milk composition						
Crude protein (%)	1.8923	0.4760	0.0004	0.0842	0.0277	0.0049
Casein as a percentage of true protein (%)	95.7043	6.1059	<0.0001	-0.9668	0.3288	0.0078
Fat (%)	1.7409	0.8357	0.0476	0.1175	0.0471	0.0196
Lactose (%)	7.2808	0.7234	<0.0001	-0.1468	0.0409	0.0019
Cheese processing						
Protein recovery (%)	86.0994	4.5510	0.0003	-0.5737	0.2398	0.0965
Fat recovery (%)	103.9300	4.5683	0.0002	-0.7083	0.2742	0.0815
Cheese composition						
Moisture (%)	30.0559	4.2257	<0.0001	0.5457	0.1973	0.0199
Protein in cheese (%)	29.5445	2.2800	<0.0001	-0.2680	0.1272	0.0890

with raw milk composition changes along with changes in cheese production characteristics and cheese composition. However, the effect of these changes on product yield and net milk receipts was still unclear. To answer this question the outputs of the meta-analysis were incorporated into the Moorepark Processing Sector Model (MPSM) (Geary *et al*. 2010).

Impact of mastitis on processor profitability – Moorepark Processing Sector Model

The MPSM is described in detail by Geary *et al*. (2010; 2012b; 2013). Briefly the approach uses a mass balance milk processing-sector model that accounts for all inputs, outputs and losses involved in dairy processing. The model is a mathematical representation of the conversion of milk into dairy products [cheese, casein, butter, whole milk powder (WMP), skim milk powder (SMP), fluid milk, by-products of butter milk powder (BMP), whey powder (WP) and cream]. The proportion of milk that is directed toward the production of each product is specified in the model. The quantities of products and by-products that can be produced from the available milk pool, with given product specifications, are calculated, processing costs are estimated, the returns from the products produced are generated, the net revenue is determined (total revenue – total costs), the values per kg of fat and per kg of protein are derived and the milk price is calculated. Similar to the farm analysis, the five BMSCC categories of ≤100,000, 100,001–200,000, 200,001–300,000, 300,001–400,000 and >400,000 cells/mL were examined in the MPSM. For each BMSCC category the raw milk composition, cheese production and cheese composition variables were modified based on the findings of the meta-analysis. In addition, changes in SMP and WMP compositions were also assumed based on the available literature.

Model inputs

The key model inputs in the MPSM are the volume of milk supplied, the milk supply profile, the product mix being produced, processing costs and the product market values. In addition, specific for this analysis, the relationship between SCC and (i) the raw milk composition, (ii) cheese production and (iii) cheese composition variables were incorporated into the model as inputs.

Raw milk The volume of milk supplied in this analysis was 5,377 million litres, representative of the volume of milk processed in Ireland in 2011 (Central Statistics Office [CSO] 2011). The national mean SCC in Ireland was estimated at 281,000 cells/mL (Aine O'Connell personal communication), therefore, the 200,001–300,000 cells/mL BMSCC category was representative of the current national dairy industry and was assumed as the baseline. The baseline raw milk composition was also sourced from CSO data (CSO 2011). The findings of the meta-analysis were applied to the baseline milk composition to estimate the composition of milk for the other four BMSCC categories. The composition of raw milk assumed for each of the BMSCC categories is presented in Table 4.

Cheese production The current industry fat and protein recoveries from industry consultation were assumed to be representative of the baseline BMSCC category (200,001–300,000 cells/mL). The findings of the meta-analysis were applied to these to estimate the recoveries for each of the remaining BMSCC categories. Fat recovery decreased with increasing SCC; at a BMSCC of <100,000 cells/mL fat recovery was 94.12% which decreased to 92.70% at a BMSCC of >400,000 cells/mL. Protein recovery also decreased as SCC increased from 99.91% at a BMSCC of

Table 4. Average fat, protein and lactose content of milk for each bulk milk somatic cell count category.

	Bulk milk somatic cell count category ('000)				
	<100[3]	100–200[3]	200–300 Baseline[1]	300–400[3]	>400[3]
Annual average fat content of milk (%)	3.70	3.82	3.89	3.94	3.98
Annual average protein content of milk (%)	3.24	3.32	3.37	3.41	3.43
Annual average lactose content of milk[2] (%)	4.85	4.70	4.61	4.55	4.50
Annual average casein in protein content of milk (%)	81.53	80.57	80.00	79.60	79.29

[1]Baseline milk volume, fat and protein content of milk were sourced from CSO Milk statistics 2011 and are representative of the national milk pool and national somatic cell count.
[2]Baseline lactose content of milk was predicted using the Moorepark Dairy Systems Model (Shalloo *et al*. 2004), the lactose content of milk for the other SCC categories was calculated using the results of a meta-analysis.
[3]Fat, protein and casein in protein content of milk for the other four bulk milk somatic cell count categories was calculated using the results of a meta-analysis.

<100,000 cells/mL to 98.76% at a BMSCC of >400,000 cells/mL.

Product composition Table 5 summarises the cheese, SMP, WMP and butter compositions assumed for each of the BMSCC categories.

Utilising the baseline (200,001–300,000 cells/mL) cheese moisture (35.26%) and cheese protein (24.50%), the findings of the meta-analysis were applied to calculate the SCC adjusted moisture and protein content of cheese. Very little literature is available on the relationship between SCC and the composition of SMP and WMP. The baseline composition of SMP and WMP (200,001–300,000 cells/mL) assumed in this analysis was reflective of the average composition of these products in Ireland (industry consultation). The composition of SMP and WMP for each of the other BMSCC categories was calculated using the incremental changes from the baseline as reported by Rogers and Mitchell (1989) and Auldist *et al*. (1996), respectively. There was no literature to support a change in butter composition as SCC increased, therefore the baseline was assumed throughout.

Each of these inputs was incorporated into the MPSM for each BMSCC category. The MPSM estimated the net revenue, the value per kg of fat and per kg of protein and the price per litre of milk within each BMSCC category.

Processor Results

Production volumes As BMSCC increased from <100,000 cells/mL to >400,000 cells/mL the quantity of cheese, butter, WMP, SMP and WP that could be produced from the available milk pool decreased by 4,217 (21.%), 623 (0.5%), 9,881 (9.6%), 7,568 (3.0%) and 2,052 (2.1%) tonnes, respectively. The potential volumes of cheese that could be manufactured highlighted that the reductions in the fat and protein recoveries were more significant than the increases in the milk solids content.

Revenue As BMSCC increased from <100,000 cells/mL to >400,000 cells/mL the net revenue generated decreased by 3.2% or €51.3 million per annum (Table 6). This reduction was driven by the reduction in the quantity of product available for sale.

Milk price As BMSCC increased from <100,000 cells/mL to >400,000 cells/mL

Table 5. Composition of dairy products produced for each bulk milk somatic cell count category assumed in the Moorepark Processing Sector Model

Product	**Bulk Milk Somatic Cell Count category ('000)**				
Cheese[1]	**<100**	**100–200**	**200–300 Baseline**	**300–400**	**>400**
Fat (%)	35.00	35.00	35.00	35.00	35.00
Protein (%)	25.92	24.66	24.50	24.39	24.39
Lactose (%)	1.39	1.39	1.39	1.39	1.39
Moisture (%)	34.40	34.94	35.26	35.48	35.49
SMP[2, 5]	**<100**	**100–200**	**200–300**	**300–400**	**>400**
Fat (%)	1.00	1.00	1.16	1.16	1.23
Protein (%)	33.00	33.00	35.37	35.37	35.93
Lactose (%)	54.00	54.00	52.17	52.17	51.28
Moisture (%)	4.00	4.00	3.05	3.05	3.18
WMP[3, 5]	**<100**	**100–200**	**200–300**	**300–400**	**>400**
Fat (%)	27.00	27.00	27.60	27.60	27.30
Protein (%)	25.00	25.00	28.30	28.30	27.50
Lactose (%)	40.00	40.00	25.70	35.70	37.30
Moisture (%)	3.00	3.00	2.80	2.80	2.70
Butter[4]	**<100**	**100–200**	**200–300**	**300–400**	**>400**
Fat (%)	84.00	84.00	84.00	84.00	84.00
Protein (%)	0.59	0.59	0.59	0.59	0.59
Lactose (%)	0.79	0.79	0.79	0.79	0.79
Moisture (%)	14.50	14.50	14.50	14.50	14.50

[1]Protein and moisture percentage of cheese calculated using results of meta analysis.
[2]SMP composition <100,000 and 100,001–200,000 cells/mL assumed generic values, unaffected by SCC. Incremental changes in SMP composition calculated based on Rogers and Mitchell (1989).
[3]WMP composition <100,000 and 100,001–200,000 cells/mL assumed generic values, unaffected by SCC. Incremental changes in WMP composition calculated based on Auldist *et al*. (1996).
[4]No evidence to suggest a change in the composition of butter, BMP, or WP as SCC increased.
[5]SMP: skim milk powder; WMP: whole milk powder.

the average milk price decreased by 0.96 cents per litre.

Component values of milk The value per kg of fat decreased by €0.04 cents/kg and the value per kg of protein decreased by €0.24 cents/kg as BMSCC increased from <100,000 cells/mL to >400,000 cells/mL (Table 6).

Industry Profitability and Mastitis

The farm and processor analysis were combined to examine the impact of mastitis on overall industry profitability. The values per kg of fat and protein calculated in the MPSM were incorporated into the MDSM to estimate the net farm profit and the margin per litre for each BMSCC category. This calculated net farm profit and margin per litre accounted for (i) the farm specific costs of mastitis and (ii) the processor effects of mastitis (the returns at processor level as BMSCC changed were incorporated into the farm analysis *via* the euro value per kg of fat and protein). This analysis generated a net farm profit of €43,328 for a 40 hectare farm with a

Table 6. Annual net revenue, milk price and component values of milk for each bulk milk somatic cell count category when 5,377 million litres/year were processed into a representative mix of dairy products in the Irish dairy industry

	Bulk milk somatic cell count category ('000)				
Financial outputs	<100	100–200	200–300 Baseline	300–400	>400
Net revenue (€m)[1],	1,617.2	1,591.2	1,571.4	1,559.8	1,565.9
Milk value (cents/L)[2]	30.08	29.59	29.22	29.01	29.12
Component values of milk in the milk pricing system					
Fat value/kg (€)[3]	3.03	2.99	2.95	2.94	2.99
Protein value/kg (€)[4]	5.99	5.89	5.83	5.78	5.75

[1]Net revenue (total revenue – total costs).
[2]Average milk price paid throughout the year (net revenue/total volume of milk processed).
[3]Average value per kg of fat paid throughout the year within the milk pricing system.
[4]Average value per kg of protein paid throughout the year within the milk pricing system.

BMSCC <100,000 cells/mL, decreasing to €18,490 with a BMSCC of >400,000 cells/mL, a difference of €24,838 (Table 7). This equated to a margin of 8.4 cents/L at a BMSCC of <100,000 cells/mL and 3.6 cents/L at a BMSCC of >400,000 cells/mL (Table 7).

To estimate industry returns (farm and processor) the margin per litre for each BMSCC category was multiplied by the volume of milk supplied nationally by dairy farmers to milk processors within each BMSCC category.

Industry returns

National BMSCC profile To estimate the SCC profile of the national milk pool, analysis was carried out by O'Connell (personal communication) examining bulk tank milk quality data from ten Irish milk processors representing 11,444 suppliers from across the Republic of Ireland. In total 687,821 records of SCC were available for inclusion in the analysis across 63,166 herd-years. The data was analysed using SAS 9.3 (SAS, 2010). The dataset was stratified into each of the five BMSCC categories from <100,000 to >400,000 cells/mL and the percentage of monthly observations in each BMSCC category was calculated. The proportion of the national milk pool supplied within each BMSCC category was calculated by multiplying the monthly milk supply profile by the monthly SCC profile of milk supplied. The calculated proportion of the national milk pool

Table 7. Impact of mastitis on the financial outputs of Irish dairy farms across 5 somatic cell count (SCC) categories incorporating the returns at processor level, holding land area constant at 40 hectares

	Somatic Cell Count Categories ('000 cells/mL)				
	<100	100–200	200–300	300–400	>400
Total farm receipts (€)	204,160	201,081	199,602	196,540	195,804
Total farm receipts/kg (cents/kg)	38.37	38.33	38.47	38.07	38.12
Total farm costs €	161,085	164,994	172,749	173,536	177,343
Total farm costs/kg (cents/kg)	30.27	31.45	33.30	33.62	34.53
Net farm profit (€)	43,328	36,280	26,954	23,071	18,490
Margin per litre (cents/L)	8.4	7.1	5.4	4.5	3.6

supplied within each BMSCC category is presented in Table 8. These proportions were applied to the volume of milk processed nationally in 2012 (5,224.7 million litres; CSO 2012) to estimate the volume of milk supplied within each BMSCC category.

Industry returns The current industry returns were calculated by multiplying the margin per litre for each BMSCC category by the volume of milk supplied within each BMSCC category nationally and summing the five calculations. This value represented the baseline industry returns.

A movement of producers from one cell count category to the next lower cell count category where possible (i.e. at lowest cell count category there is no movement), was examined. Three scenarios were explored, i.e., a 10% movement, 20% movement and 30% movement of producers from higher to lower SCC categories. Table 8 summarises (i) the proportion of milk supplied within each BMSCC category and (ii) the national average SCC for the baseline and scenarios analysed. The improved industry returns were again calculated by multiplying the margin per litre for each BMSCC category by the volume of milk supplied within each BMSCC category and summing the five calculations.

Industry Results

The gains in industry returns due to the 10–30% movement from one cell count category to a lower one were calculated as the difference between the baseline industry returns and the improved industry returns (Table 9). A 10% movement in milk supplies from higher to lower BMSCC categories saw an increase in industry returns relative to the baseline of €6.6 million per annum, increasing to €19.4 million per annum with a 20% improvement in milk supplied and €37.7 million per annum with a 30% improvement in milk supplies.

Discussion

This analysis highlights that the costs of mastitis are incurred across the dairy industry. While the largest component of the cost is at farm level, the processing industry is also incurring a share of the costs. The opportunity across the industry of improving the national average BMSCC is significant and readily achievable. A reduction in the national BMSCC of 10,000 cells/mL would result in an estimated industry gain of €6.6 million per annum, thus highlighting the value of a national mastitis programme. This is considering only moderate improvements;

Table 8. Proportion of suppliers producing milk within each bulk milk somatic cell count category currently and the assumed improvement in suppliers examined in the scenario analysis

Proportion of producers in each BMSCC[1] category (,000 cells/mL)	Current	Scenarios		
		10% Movement[2]	20% Movement	30% Movement
<100	3.3	5.9	11.2	19.5
100–200	25.8	26.5	27.7	28.4
200–300	33.6	32.5	30.2	27.1
300–400	21.9	21.2	19.8	17.2
>400	15.4	13.9	11.1	7.8
National average somatic cel count (cells/mL)	281,432	271,760	262,088	252,415

[1]BMSCC=bulk milk somatic cell count.
[2]10%, 20% and 30% movement refers to a movement of producers from one cell count category to the next lower BMSCC categories where possible, i.e. lowest cell count category there is no movement.

Table 9. Incremental gain in industry returns for each improvement in milk suppliers scenario examined

Analysis	National average BMSCC[1] (cells/mL)	Incremental gain relative to the baseline national returns, €m
Current	281,432	0.0
10% movement[2]	271,760	6.5
20% movement	262,100	19.4
30% movement	252,420	37.6

[1]BMSCC=bulk milk somatic cell count.
[2]10%, 20% and 30% movement refers to a movement of producers from one cell count category to the next lower BMSCC categories where possible, i.e. lowest cell count category there is no movement.

more significant improvements would substantially increase the value of the Irish dairy industry.

Expansion Post-2015

The removal of milk quota by 2015 (CAP Health Check 2008) presents a wealth of opportunities for the Irish dairy industry. In anticipation of this the Department of Agriculture, Food and the Marine in Ireland have set a number of dairy industry targets to be achieved by 2020, the most significant of which is a 50% increase in the volume of milk produced by 2020 (Food Harvest 2020, Department of Agriculture, Food and the Marine 2010). Considering the current national average BMSCC of 281,432 cells/mL and a national herd of 1,060,300 (CSO 2012); reducing this BMSCC by 100,000 cells/mL results in an estimated increase in milk output of 142.1 million litres nationally, equating to 5% of the *Food Harvest 2020* target. Expansion in Ireland is well underway with an additional 100,000 dairy replacement heifer calves born in 2012 relative to 2008 (Shalloo, Ryan and French 2012). Expanding herd size in the presence of high herd SCC will present many challenges (i.e. management, high on farm costs etc.) and may limit the number of cows that one individual can carry. As the Irish dairy industry is expanding farmers and processors need to be aware of the costs associated with mastitis and focus on it to motivate themselves to implement effective mechanisms to reduce the impact on farm and processor returns.

Effective mechanisms

As demonstrated in the analysis presented here, as BMSCC increased, milk price decreased and the values per kg of fat and protein decreased which was not linear. There was a significant advantage of reducing cell count even under the lower cell count categories. For example a reduction in cell count from the 200,000–300,000 to the 100,000 to 200,000 cells/mL category resulted in a milk price increase of 0.37c/L. Payment systems, either in the form of a penalty or bonus or both, are effective tools to encourage reductions in the national BMSCC profile (Sampimon, Sol and Kock 2005, Valeeva, Lam and Hogeeven 2007). Currently many Irish milk processors continue to pay the base milk price up to a BMSCC of 400,000 cells/mL, only imposing penalties after this BMSCC threshold. Such a system (i) does not incentivise farmers to reduce BMSCC below 400,000 cells/mL, implying that they only need to meet the EU regulations and (ii) does not optimise farm and processor returns. The analysis presented in the current paper showed that there should be a difference of 0.96 cents per litre between milk supplied with a BMSCC of ≤100,000 cells/mL and milk supplied with a BMSCC of >400,000 cells/mL. Incorporating this into a payment system would send a strong and serious signal to farmers that (i) keeping the farm BMSCC below 400,000 cells/mL is not sufficient and (ii) reinforcing this point by highlighting that a BMSCC <100,000 cells/mL is optimal. International research emphasises the importance of a blended penalty bonus system which seeks to reduce high SCC milk producers and maintain low SCC milk producers (Berry *et al*. 2006; Nightingale, Dhuyvetter and Schukken 2008).

CellCheck is the national mastitis control programme in Ireland which is coordinated and facilitated by Animal Health Ireland. This programme provides the knowledge to reduce SCC on farm, however raising awareness of the costs of mastitis at farm level is the first step in reducing the national SCC (Lam *et al.* 2007; Huijps *et al*. 2008). To assist this farmer awareness/education process many tools have been developed internationally: the Dutch cost of mastitis tool (Huijps *et al*. 2008) the New Zealand SmartSAMM Gap Calculator and the Australian Countdown Down Under Mastitis Model (Larcombe and Shephard 2004). Based on the success of these tools a similar decision support tool was developed for Ireland (CostCheck) using the analysis carried out by Geary *et al*. (2012). This tool is available on the Teagasc and Animal Health Ireland websites.

Conclusions

The analysis presented here highlights that the current national average BMSCC of 281,000 cells/mL has a considerably negative impact on farm, processor and overall industry profitability. If corrective measures are not taken at farm and processor level the unrealised potential of the national industry in terms of milk production, dairy product volume and dairy product quality will become more significant as the industry expands. Ongoing communication of these messages is essential to raise awareness at farm and processor level. Thereafter, the implementation of effective bonus/penalty payment systems and the continuous provision of on-farm supports highlighting best practices are key to reducing the national average BMSCC.

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