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**A literature review; Mastitis, its forms, causative agents,
predisposing factors and treatments**

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**A comparison of incidence of mastitis between three
Irish dairy farms, and the effect of season on its
occurrence**

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List of Abbreviations

SCC-Somatic Cell count

BMSCC-Bulk Milk Somatic Cell Count

ICSCC-Individual Cow Somatic Cell Count

CM-Clinical Mastitis

SCM-Subclinical Mastitis

IMI-Intramammary Infection

IRCM-Incidence Rate of Clinical mastitis

BDCT-Blanket Antibiotic Dry Cow Therapy

SDCT-Selective Dry Cow Therapy

Abstract

The season is an important predisposing factor for intramammary infections such as mastitis to occur, and may play an important role in influencing the frequency of udder health issues in a herd scale. The aim of this study was to determine how much of an effect the season had on the average monthly SCC recorded in three dairy herds, known in this study as Farm A, Farm B and Farm C. These three dairy herds are all located in the eastern Republic of Ireland, and would have experienced the same climatic conditions in the period of study, and are assumed to have the same practices performed as regards to milk recording, housing and grazing.

The animal husbandry system in Ireland is based on keeping the animals on pasture for the majority of the year, until the winter when the conditions will no longer allow for grazing. This gives a clear separation between the winter housing period and the rest of the year. The expected trend in the data analysed was the increase of herd average SCC during housing, with lower numbers seen in the spring and summer.

The data was analysed by calculating the average SCC of the herd on a monthly basis for each of the three farms. In addition, the median values were also found. From this data, it was possible to discern the trends in the data throughout the period of milk recording for each of the three farms. Significantly elevated individual milk recording results had the effect of driving up the herd average SCC, which could potentially give an erroneous impression of the true overall udder health situation in each herd. Therefore, in addition to the average SCC measurements, an average was calculated for each herd where significantly high scoring cows were omitted from the analysed data. The threshold set for this study was 1 million somatic cells/ml milk.

The data before exclusion of high scoring cows gave no indication of there being an increased propensity for subclinical or clinical mastitis in winter, in fact the highest cell counts were in some cases found in the summer. After exclusion, the data set indicated a situation more closely resembling the expected seasonal influence, where the period of housing recorded the highest SCC numbers below 1 million cells/ml. The significance of these findings however was deemed to be insufficient to provide evidence for conclusion that the incidence of mastitis is higher in the winter season in the Irish system. There is however enough evidence to suggest that the season will have a significant influence on the herd SCC, where the summer period will have more cases of exceedingly high scoring cows.

Introduction

Mastitis is the name given to the inflammation of the udder of dairy cattle, and can be both clinical and subclinical in nature. The disease is a multifactorial disease, which can be caused by both contagious and environmental agents, as well as physical agents. Mastitis can be caused by bacteria, which are chiefly from the genera *Staphylococcus*, *Streptococcus*, *Bacillus* and *E-coli* (Ferrerira *et al.*, 2018). The bacterial causative agents causing clinical and subclinical mastitis are further divided into infectious and environmental pathogens, with a third category comprising of pathogens categorised as in-between the two other categories. Non-bacterial agents causing mastitis in dairy cattle include algae and fungal pathogens, whereof algae such as *Prototheca zopfii* are increasing in importance worldwide (Möller *et al.*, 2007).

Globally mastitis is one of the most important dairy herd diseases, as it is extremely common in most dairy herds, and also due to the economically detrimental effects on the dairy industry (Guimarães *et al.*, 2017). In Canada, it is regarded as one of the costliest diseases present in the dairy sector, with the average expenditures for each clinically or subclinically infected cow reportedly being 662 Canadian dollars annually (Belage *et al.*, 2019). The economic impact of subclinical mastitis is due to the milk yield of the affected cattle being significantly reduced, an effect that will persist throughout the course of the disease (Archer *et al.*, 2014). In clinical mastitis, the milk is not fit for human consumption before treatment.

The prevalence of the disease can be significantly increased or decreased depending on the environmental factors, such as environmental hygiene, and good practice during milking with adequate teat dipping (Dufour *et al.*, 2012), as well as other factors such as parity, stage of lactation and season (Moosavi *et al.*, 2014).

In this paper, a comparison will be made of the general prevalence of mastitis in three Irish dairy herds based on SCC, as well as examine the effect of the season on the occurrence of udder diseases in the Irish system. In Ireland, due to the climate and grass conditions, dairy cattle are kept on pasture for the majority of the year and only taken into housing in the winter months when the conditions don't allow for grazing. In contrast, for example the Hungarian model of husbandry is based on indoor keeping of cattle, feeding them with corn silage and other types of fodder. This type of husbandry system would likely have a different udder health situation than the Irish system that will be examined in this paper.

Literature review

Mastitis is the name given to the inflammation of the udder of mammals, and it is one of the most significant herd diseases in dairy cattle husbandry (Guimarães *et al.*, 2017).

There are two main categories of mastitis in dairy cattle, which are clinical and subclinical mastitis. The main difference between these two categories is the presence or absence of clinical signs that can be seen on physical examination of the animal. Clinical mastitis will normally be visible upon inspection of the animal, with symptoms such as pain, inflamed redness, swelling and physical changes in the milk (Østerås *et al.*, 2006). The animal often displays general clinical signs such as fever and anorexia. Subclinical mastitis however, will not show any symptoms of the disease, and we must rely on diagnostic tests to diagnose a cow. Subclinical mastitis will lead to a significant decrease in the milk production in heifers and cows, as well as increasing medical costs, labour costs, fines for increased SCC and losses due to the discarding of milk (Diagnosis and treatment of mastitis in dairy herds, Clinic of Large animals, ÁTE). Clinical mastitis can lead to severe clinical signs that can lead to the milk that is produced being unusable, as well as eventually it can lead to the complete cessation of milk production in one or more quarters of the affected cattle. In peracute cases of clinical mastitis, general signs can be quite severe, causing septicaemia which can in some cases lead to death (Roussel *et al.*, 2017).

Mastitis, most commonly, is caused by bacteria and other pathogenic microbes such as fungi or algae. Physical causatives like chemicals or mechanical damage to the udder can also lead to the inflammation of the udder tissue, causing the same clinical signs. Bacterial mastitis is caused by infection of the udder tissue by pathogenic bacteria, that can enter the udder either through the milk duct in an ascending fashion (galactogenic), through the bloodstream (hematogenic or lymphogenic) and through injuries to the skin or mucous membranes of the udder, often caused by faulty or improperly operated milking machines.

The occurrence of clinical mastitis can be monitored and studied by logging cows with clinical signs, using diverse laboratory methods, or locally using the California mastitis test (Rossi *et al.*, 2018). The California mastitis test will indicate a higher SCC by lysing the cell membranes of somatic cells, using a specific reagent. This will make the DNA and proteins of the cells precipitate in the milk, causing a characteristic and recognisable change in viscosity of the milk (Plummer & Plummer, 2012). It is not however a quantitative test, so to diagnose and quantify the affected cattle in the case of subclinical mastitis, we need to use

the specific SCC as indicators (DeVries *et al.*, 2012). An elevated SCC count in the milk will indicate the presence of an intramammary inflammation. According to EU regulations, milk with a SCC higher than 400 000/ml is not suitable for sale on the consumer market. This is often regulated by testing the bulk tank milk, which consists of milk from all the milking cows in the herd. This is known as composite milk SCC (CMCC) (Nørstebø *et al.*, 2019). The bulk tank milk should not have an SCC count which violates the EU threshold.

A breakdown of the pathological agents causing mastitis

As previously mentioned, mastitis can be categorised by the nature of the pathogen, by the clinical or subclinical forms of the disease and by route of infection. Bovine mastitis pathogens are further distinguished into different groups, based on how the bacteria are transmitted. The pathogens can be either environmental, contagious or belonging to a third group which are known as “in between” causatives (Abebe *et al.*, 2016).

Environmental causative bacteria do not spread between the animals directly, but will infect the udder from the environment. This kind of mastitis can be connected to poor hygiene, with an increase of faeces or dirty bedding and puddles in the barn. Environmental pathogens such as *Escherichia coli* & *Streptococcus uberis* make up 50% of clinical mastitis cases (Mayne *et al.*, 2011).

Contagious causative agents directly transmit from animal to animal, through direct contact or through contact with the cups of the milking machine. These infections tend to cause chronic mastitis, often subclinical in nature, however the infections may flare up and cause clinical symptoms (Abebe *et al.*, 2016).

In-between pathogens, such as *Streptococcus dysgalactiae*, can be seen as a hybrid of the two other forms. They will act chiefly as environmental causatives, but also retain the ability to infect through unhygienic milking practice and direct contact. They can be found in the tonsils, mouth and vagina of cows, and the bacteria have the ability to invade mammary epithelial cells. This means that *S. dysgalactiae* can persist in mammary gland, despite chiefly propagating in the environment (Quinn *et al.*, 2011).

Geographic differences occur in the distribution of the different mastitis pathogens. For example, in Norway, *Staphylococcus aureus* and *Streptococcus dysgalactiae* are the most significant and common mastitis causative agents (Østerås *et al.*, 2006), while in parts of the

US, Coliforms such as *E coli* and *Klebsiella* represent a higher percentage of cases. New Zealand will have a higher isolation rate of *Streptococcus uberis* than coliforms (Olde Riekerink *et al.*, 2008).

Examples of contagious mastitis pathogens

Staphylococcus aureus

S. aureus is an important and fairly common contagious pathogen in dairy herds. It has the ability to colonise the skin of the teats, and infect the teat canals in an ascending fashion. Infections can also enter to the mammary glands from the udder, which is an important way of infection for the pathogen. Incorrect milking practice is the most common way of transmission between animals, as the workers or the milking cups can act as mechanical vectors of the bacterium. *S. aureus* has a very specific way of propagation in the milk ducts, with its main habitat within the udder being in the milk collecting ducts and alveoli. This gives *S. aureus* the ability to “hide” from attempted intramammary antibiotic infusions, making the infection harder to treat. The disease will often have episodes of periodic shedding of the bacteria, causing intermittent clinical mastitis. It often causes a chronic form of inflammation; however, its effects can range from peracute clinical signs to a subclinical variety of mastitis. In some extreme cases, it can lead to gangrene of the udder (Quinn *et al.*, 2011).

Streptococcus agalactiae

This bacterium is an obligate pathogen, although it can survive on the environment for a short amount of time. In a similar manner to *S. aureus*, it will act as a periodical shedder, and will most often lead to a markedly increased somatic cell count of the milk. A chronic case of *S. agalactiae* will as the name suggests lead to atrophy of the milk secreting glands, leading to so called blind teats. The atrophy of the glands is caused by the blockages caused by the inflammatory reaction. This effect is usually observed to be cyclical, which means the cessation of milk production will be somewhat gradual. Usually this bacterium will not cause severe systemic signs, and usually all symptoms will be located in the mammary gland. Usually, by the time this infection becomes clinical mastitis, the damage is already done, and the milk secretory glands are usually already atrophied (Quinn *et al.*, 2011).

Examples of environmental mastitis pathogens:

Coliforms:

The most important coliforms causing udder infections in cattle are bacterial strains of *Escherichia coli*. Other coliforms that are also to blame for forms of mastitis can belong to *Klebsiella* or *Enterobacter*. The pathogenesis of *E. coli* mastitis is a little different, as it is not the bacteria themselves that cause the inflammation of the udder tissue, but rather the endotoxin produced by the bacteria. These endotoxins are able to produce a very strong reaction if the bodily response to its presence is delayed, with typical symptoms of peracute coliform mastitis being pyrexia, anorexia, depression and general signs of toxæmia. It can lead to recumbency, and can lead to death of the animal in a matter of days. At this stage, the udder and teats won't normally feel hot or swollen, but it can be recognized by the milk having a watery consistency with small flakes. Animals can also recover, if the neutrophil reaction is adequate, and in these cases the cow may even restart production of the affected quarters to a limited degree in the same lactation period. In acute cases, the serous-watery milk is the main clinical sign, with less characteristic general symptoms (Quinn *et al.*, 2011).

Acute cases end in recovery more often than peracute cases. Chronic and/or subclinical cases are known to happen, and as an environmental pathogen, in environments with a high coliform load, can cause recurrent mastitis in cattle. The best way of preventing coliform mastitis is teat sealing in the dry period as an addition to the normal dry cow therapy of intramammary antimicrobial infusions. Treatment of coliform mastitis can be tricky, as the endotoxins are responsible for the pathogenicity, not the bacteria. If you kill the bacteria, the endotoxins will be released all at once from the dead bacteria, and may cause a peracute toxæmic reaction that can kill the cow, therefore antibiotic treatment is highly debated in coliform mastitis (Royster & Wagner, 2015).

Streptococcus uberis

These bacteria can be found in a multitude of places in the body of a cow, including the tonsils, GI tract and on the hair coat. Even so, the transmission of the pathogen does not transmit from these places of replication directly to the udder of other cattle, but rather indirectly through contaminated bedding. Hence, we don't call *S. uberis* a contagious pathogen, but an environmental one. The material of the bedding will influence the growth and level of contamination of the bacteria, as it thrives better in straw than in inorganic bedding like sand (Quinn *et al.*, 2011). The bacteria can also be found in pasture. *S. uberis*

is not as dependent on adhering to the epithelium of the udder as other pathogens, although it is thought to have the capability of adhesion (Almeida *et al.*, 2006). Most *S. uberis* infections are relatively subclinical, with so called milk abnormalities being the most common clinical manifestation of infection, and with less than 10% of cases leading to systemic clinical signs. It is a very versatile pathogen, with some infections not leading to any form of clinical signs in the animal (Quinn *et al.*, 2011).

Prototheca zopfii

This is a different sort of pathogen altogether as it is not a bacterium, like the previously mentioned causative agents are. *P. zopfii* is an algal organism, which grows in colourless colonies forming biofilms on culture (Gonçalves *et al.*, 2015). This is the only known plant to cause mastitis in cattle and is an increasing problem in worldwide cattle herds (Möller *et al.*, 2007). In a polish study, it was found to be the third most common cause of mastitis in the herds they tested, which can be seen as an indication of its increased importance in the dairy sector (Jagielski *et al.*, 2019). This pathogen is particularly dangerous as there is no current treatment for the infection, and animals that are chronically infected must be culled (Jánosi *et al.*, 2001). The symptoms of a clinical infection are, among other things, a watery appearance of the milk with larger white clotting, and the shedding of the pathogen is intermittent in nature. As this pathogen can “hide” from macrophages by invading epithelium, parallels can be drawn with *Staphylococcus aureus* caused mastitis; although *P. zopfii* does not infect directly from animal to animal. However, subclinical mastitis is the most common outcome of infection, rather than the clinical form. In the above-mentioned Polish study, they found that the SCC is higher in clinical protothecal mastitis than in subclinical mastitis, and other studies would indicate an even higher contrast in the SCC of the two different mastitis forms (Jagielski *et al.*, 2019).

The biofilms that are produced by the algae is likely one of the main reasons this organism will persist in the environment of dairy farms and can be very difficult to remove. As the film will protect the organism from many detergents, it can take a high concentration of cleaning agents to remove the agent from any environment (Gonçalves *et al.*, 2015).

Risk factors increasing the incidence and prevalence of mastitis in dairy herds

Mastitis is known as a management related disease of dairy cattle, which means that it is connected with the feeding, keeping conditions and milking hygiene of the cow. The incidence of the disease is also affected by the parity of the cows, with different forms of mastitis being common at different life stages. Older cows are more likely to develop chronic clinical mastitis due to a higher exposure time to environmental pathogens, and the fact that they have been milked more. Studies will indicate that mastitis will generally be an increasing problem for a cow as the parity increases, with a higher SCC in older cattle than in heifers or two-time calvers (Jingar *et al.*, 2014).

Hygiene as a predisposing factor

An important predisposing factor for the development of intramammary infections (IMI) caused by environmental pathogens is the level of hygienic management of the dairy farm. Dirty bedding, manure contaminated passageways or stalls and dirty legs and udders of the cows can all act as reservoirs for environmental mastitis causative agents. Different risk factors will be present for different types of bedding. Coliform count can be reduced by using sawdust (567.54 ± 5.06 cfu/ml), compared to using a rubber mat (2523.5 ± 3.16 cfu/ml) in the stalls, as well as reducing the total bacteria count (Madushanka *et al.*, 2017).

The area of rest for a cow is an important factor in the development of IMI, as the teat ends of the cow can be contaminated by the surface it is lying on. Therefore, the intended surface or bedding must be kept clean, and if bedding is used, it must be regularly changed out. Due to the extended periods a cow spends lying down, either in rumination or rest, the effect of the bacterial load of the environment can be very significant. Cattle can spend 50-65 % of their time in the prone position (Madushanka *et al.*, 2017). This risk is an even bigger factor in the first 30 minutes after milking, as the teat canals are still open in this period of time. There can be significant benefits to feeding cattle immediately after milking to keep them standing in the refractory period after milking.

Increasingly, the bedding used for cattle kept indoors is known as CBP; which is compost bedding pack systems. This is a system based on using organic materials, such as sawdust, which will act as substrates for decomposition and which will be supplemented by the cows adding faeces and urine. (Fávero *et al.*, 2015). To use this system, you will need to till the bedding often using either automatic or manual tilling of the bedding. This mixes the components together and introduces oxygen, which is essential to the microbiological

breakdown of the manure (Eckelkamp *et al.*, 2016). This system has different risk factors involved compared to traditional straw bedding systems. Some pathogens prefer to reproduce in sawdust than in straw, whilst some bacterial growth is inhibited on CBP bedding.

In some systems, the areas of rest, feeding and other areas of the confined space are not partitioned by fences or stalls. This is called freestall keeping, and it means that cows will lie down anywhere, including areas which are often contaminated by faeces or urine. As a result, it is very important that the bedding is regularly changed in the freestall area, as any accumulation of contaminated matter will increase the microbiological load on the animals causing an increased incidence of management related diseases (Eckelkamp *et al.*, 2016).

As well as the bedding, contamination of the cow itself can also be a risk factor for intramammary infections. Faecal contamination of the legs and udder can increase the bacterial exposure to the udder tissue, often with environmental pathogens commonly found in faecal material. The degree of hygiene of the areas of concern can be judged using a hygiene score, which ranges between 1 and 4, where 1 is practically clean and 4 is caked and/or completely covered with dirt (Schreiner & Ruegg, 2002). Dirty teats can also have an impact during and after milking, as inadequately cleaned teat ends can expose the open milk ducts to a higher bacterial load after milking. The total bacterial count of the milk will also be increased if proper udder hygiene is not adhered to before milking (Schreiner & Ruegg, 2003). Sufficient cleaning and drying of teat ends can be of significant importance for decreasing the incidence of mastitis, even compared to dry cow therapy (Schreiner & Ruegg, 2003).

Milking as a predisposing factor

Modern milking is performed by milking machines, in essence consisting of 4 rubber lined cups that attach to the udder. The lining of the cups provides mechanical stimuli for the teats, and the system will provide a set vacuum to achieve the extraction of milk. Incorrect use or improper vacuum parameters can cause mechanical damage to the teats or udder, which can predispose to infection. This effect is sometimes known as overmilking. Overmilking is characterized by for example using inappropriate liners on the milking cups, clusters that are too heavy for the udder and incorrect strength and/or spacing between pulsation of the milk liners (Hillerton *et al.*, 2002).

The good hygiene practice of milking is of significant importance, as the milking cups may be a source of pathogenic microorganisms if not used correctly. The milking of the animal plays an active role in introducing bacteria into and onto the teat canal (Neijenhuis, 2011). If you use the same clusters for animals suffering from mastitis on other healthy animals, it will spread the bacteria from the teat skin and milk of the affected cow to the next cow in line. Because of this, it is often advised to milk all mastitic cattle at the end of milking, or use special machines on the affected animals that won't also be used on the others. On top of this, the act of milking the animals won't only cause an increased risk of spreading bacteria between animals using the same cluster, but also between quarters of an affected animal. This is because of some claw systems having fluctuating vacuum, which leads to milk from one quarter entering the cups attached to another quarter. The vacuum and pump action of the teat cups will also open the teat canal wide enough, and create an opportunity for bacteria to be pushed in through the teat canal. This is done by a vacuum impact which momentarily pushes against the teat sinus and opens it up enough to possibly be infected by any pathogenic bacteria present (Neijenhuis, 2011).

If the milking claws are too light, or attached before milk let down, the udders may be insufficiently milked out when the cups are removed. Retained milk may cause udder health problems, and it is important to ensure that the milk has been let down before attaching the cups. This is easiest achieved by manipulating the teats approximately 90 seconds before attaching the cups. The manual stimulation of handling the teats causes an oxytocin release, starting the process of milk let-down. In practice, the manipulation is most often done when cleaning the teat ends before commencement of milking (Neijenhuis, 2011).

Prevention of the infection of the udder due to the milking practice is therefore dependant on avoiding poor milking practices like overmilking, using faulty milking machinery, bad techniques and poor hygiene (Hillerton *et al.*, 2002). To improve on issues related to milking, it is good milking practice to dip the teat ends in disinfectant solution pre or post milking. The idea behind this is to remove the microbacterial load on the teat ends, so they won't infect the open teat end during or after milking. The most common substances used to disinfect teat ends are iodine-based compounds and chlorhexidine. Some studies will indicate that pre dipping before milking has a lower efficacy than post-dipping (Kamal & Bayoumi, 2015).

The hygiene of the milkers hands can also play a major role in the transmission of agents between the udders of animals. As the hygiene of the milking has such an important role, the attitude of the milkers handling the cattle every day has a significant effect on the efficacy of attempts to establish good milking practice. If the milking is performed by employees at a farm, and not by the owner, it is of considerable importance that the employee's needs are fulfilled, both in work satisfaction and financial compensation. Some studies will indicate that the employee attitude toward farm hygienic practices are dependent on job satisfaction (Múnera-Bedoya *et al.*, 2017).

As previously mentioned, it is also of good practice to keep the cows standing for at least 30 minutes after milking, to prevent the animals lying down whilst their teat duct openings are open.

Season, temperature, humidity and feeding systems as predisposing factors

The previously mentioned predisposing factors are all the most commonly discussed factors for the increased incidence of clinical or subclinical mastitis. In addition to these however, the season can have significant impact on the frequency of mastitis cases in a herd, something that will be explored in later parts of this paper. Increased temperature or humidity can create better conditions for microorganisms in an environment, as well as create husbandry conditions that lends itself to a higher degree of udder health issues (Moosavi *et al.*, 2014).

The SCC of the bulk tank is understood to have a seasonal pattern, which is dependent on the calving system of the herds. In herds that calve all year round, without seasonal preference, the highest SCC is normally in the summer months of June-July. The individual cow SCC is shown to be higher in the late summer, in July-August in year-round calving units (Olde Riekerink *et al.*, 2007). This all differs from the seasonal calving farms, where animals will calve in the winter months of January-April in the Northern hemisphere. An example of this type of system is Ireland, where the majority of dairy farms will have a seasonal calving pattern, with the cattle being on pasture for most of the year. In New Zealand, where they are also employing a seasonal calving system, the highest BMSCC will be found in their winter months of June-September.

One study shows that the SCC of animals are normally higher and more variable in the spring and summer, while the bulk milk SCC is lower in this period in Ireland, which has more of a seasonal calving, pasture-based system (Archer *et al.*, 2013). This however does not mean

that udder health is of less importance to Irish farmers in this period, as the BMSCC does not rule out individual animals with clinical or subclinical mastitis (Archer *et al.*, 2013). This underlines the difference between BMSCC and ICSCC.

There is normally an increased SCC or an increased IRCM in indoor keeping systems in the hot summer months. This can be correlated with a few different factors, one of which is heat stress (Vitali *et al.*, 2016). Heat stress is the name of the condition where the animals produce or are exposed to too much heat and/or humidity, and are unable to rid themselves of the excess. Heat stress will cause a negative reaction in animals which will compromise their immune system making them more prone to any sort of infection, including mastitis. Biological functions of an animal are linked to homeostatic conditions in the animal, which is harder to achieve in an environment of high heat and humidity. The animal will have to devote more energy to maintaining homeostasis, which will affect the animal negatively. Because of this, the heat stress in itself can also lower the milk production of an animal, making it an economic issue in the dairy sector which is growing due to global warming (Polsky & von Keyserlingk, 2017). Summer heat stress is estimated to cause a loss of 897 million US dollars a year, due to reduced milk yield, reproductive losses and disease caused by immune function being impaired (Spiers *et al.*, 2018). Heat stress is also said to be responsible not just for the reduction in milk production, but also negative changes in milk quality, including reduction of milk fat and protein (Dahl, 2018).

The reduction in milk quantity can be more accurately described as being due to the natural reaction of the cattle to decrease feed intake, if exposed to heat stress. Dairy cattle are already creating more internal heat due to the milk production, as a result of the extra feed digestion in the rumen, the external effects of heat and humidity will cause an accumulation of heat further exacerbating the issue. If the cattle are being kept together in confinement in a shed, they will all contribute to a higher ambient temperature in the room. In the US industry, losses due to heat stress are said to be between 1,69-2,36 billion US dollars (Polsky & von Keyserlingk, 2017). One of the reasons for the above-mentioned immune deficiency created by heat stress is the endocrine effect of the heat, causing lower amount of cortisol in chronic conditions. This leads to an elevated leukocyte count in the blood which causes a malfunction of the immune system. In addition, some studies indicate that these leukocytes can be partly responsible for increases SCC in affected animals (Dahl, 2018).

In outdoor systems, the issues are normally different, as well as the common pathogens. On pasture, *S. uberis* is a more important environmental pathogen, while in housing *E. coli* is more common in causing a higher IRCM (Olde Riekerink *et al.*, 2007). On pasture, there are generally less issues with ventilation, and the cumulative heat production of animals is no longer a factor. This means that in pasture-based systems, such as the Irish or New Zealand systems, heat stress will be less likely and have less of a direct correlation with mastitis. Conversely, the period with a higher degree of mastitis will most likely be later in the year after the animals have been placed inside sheds or other housing facilities. This would be due to the hygiene conditions of housing facilities being of a lower standard than the pastures the cattle spend their summers in. By being able to keep cattle outside in the hottest months, the effects of heat stress and hygiene conditions favouring the occurrence of intramammary infections (Dahl, 2018).

To mitigate the effect of heat on animals at pasture, there are several ways of cooling them down. Shade is an important factor that should be in place to prevent the animals from overheating in the sun. This can be provided naturally by trees in or around the field, or in cases where trees are not present, artificial shelters from the sun can be erected in pastures for grazing. There should be 5,8 m² of shade area for each cow according to some studies (Dahl, 2018), and shadders need to be usable throughout the day, accounting for the movement of the sun.

As heat and humidity increase, the chances of heat stress are higher. This means that efforts must be made to reduce the impact of the heat on the dairy herd. In indoor systems this is often done by increasing ventilation, which is a good way of relieving some heat. However, in very hot conditions, a common way of cooling the cattle is using water-based cooling systems to “shower” the cattle periodically (Dahl, 2018). This can create puddles on the ground, which can provide an excellent media for bacterial growth. Once cattle start lying down in these puddles, these pathogens can access the teat canals and teat skin, increasing the bacterial load on the udder. This is another way heat can cause problems in a herds’ general udder health. A combination of decreased immune response due to heat stress, and an increased bacterial load will inevitably lead to a higher prevalence of mastitis in the herd, as well as a general regression of milk quantity and quality.

As mentioned, there are several methods of cooling utilised in housing units, each with different factors to consider. Fans are often utilised over the bedding area of the cow, as well

as some people using other forms of active cooling like soaking mechanisms in the housing unit. To try and prevent puddles forming in bedding areas, one solution is to soak the cows in the feeding area, and let the water evaporate in the bedding area using fans. The efficiency of fans is dependent on the temperature of the air. Because the air will be cooler during night time, some studies will indicate that cooling the cattle during the night will have a larger positive effect on total milk yield than day time fan cooling (Spiers *et al.*, 2018).

Another method of active cooling is misting, which will cool the animals down while avoiding the issue of pools being formed on the ground. This, however, is only an option if the ventilation is adequate in the housing area, as a too high degree of mist in the air can decrease the air quality and cause respiratory issues. Cattle also show behavioural traits indicating attempted avoidance of sprinkler systems, especially around the head area, which could indicate that cattle are not naturally inclined to use water as a cooling method (Polsky & von Keyserlingk, 2017).

Treatment and prevention of mastitis

In modern treatment of mastitis cases, there are more things to consider than just to diagnose an animal with clinical or subclinical mastitis and treating it. To achieve a true assessment whether or not it is worth treating an animal, parity, days of lactation, mastitis history and the average SCC of the cow must be taken into account as well as, ideally, an antimicrobial susceptibility test. Antibiotics are only to be used in cases where the affected animal would have a significant benefit from the treatment. The chances of relapse should be assessed, and any cattle with a reoccurring issue with clinical or even subclinical mastitis could be rendered ineligible for treatment (Royster & Wagner, 2015). The treatment is normally performed using intramammary infusions containing different forms of antibiotics, most commonly cephalosporins like cefalexin. However, as different bacteria will need different drugs to maintain the same efficacy of treatments, it can be beneficial to know what bacteria has caused the disease before treatment. As a complete bacterial culture is impractical and takes too long, some systems of fast culture on farm have been devised. One such system is the Minnesota easy culture system, and another is the 3M petrifilm system. Knowing the causative agent of the clinical mastitis can lower the amount of antibiotics needed in the curative effort by 50% (Lago & Godden, 2018).

Whether the causative agent of clinical mastitis is a gram positive or gram-negative organism will affect the treatment plan for each case. Gram-negative bacteria have in later years become more common as a causative organism (Lago & Godden, 2018), and in some cases caused by gram negative bacteria, antimicrobial drugs are of disputed value to the curative efforts. In case of coliform mastitis, the antibiotics could potentially lead to endotoxemia if there is a severe coliform infection in the udder, where the dead bacteria release endotoxins *en masse*. Also, for Gram positives, there are cases where the use of antibiotics can be questioned, for example in severe cases of *S. aureus* caused mastitis, there is a high likelihood of treatment not being effective (Royster & Wagner, 2015).

One relatively common way of treating mastitis, which can perhaps be seen as more preventative than curative, is the dry cow therapy (DCT). The idea behind treating cattle in the dry period is due to new infections being more common in the dry period than during the lactational period, even subclinically affecting between 13-35% of quarters (Bonsaglia *et al.*, 2017). This could be due to the effect of milking out the quarters, which will flush any pathogens without adhesion molecules out with the milk. There are two forms of DCT commonly put into practise, which is the Blanket Antibiotic Dry Cow Therapy (BDCT) and the Selective Dry Cow Therapy (SDCT) (Higgins *et al.*, 2017). The difference between these two forms of DCT is essentially the usage of antibiotics. Udder health antibiotic use is the largest portion of antibiotic usage in the dairy industry (Royster & Wagner, 2015), with a large proportion being due to BDCT.

In BDCT the idea is to treat every cow prophylactically with antibiotics to treat any underlying subclinical intramammary infections and prevent them from contracting any infections during the dry period (Higgins *et al.*, 2017). The antibiotics would be administered locally using intramammary infusions, and would in some cases be combined with a teat sealer. One such antibiotic often combined with a teat sealer is the cephalosporin cephalonium (Bradley *et al.*, 2010). This method of treating dry cows translates into a huge amount of antibiotic usage annually (Bonsaglia *et al.*, 2017). In the current climate of antibiotic resistance, it is therefore becoming more important to try and limit the prophylactic antibiotic usage.

SDCT is based on screening cattle for IMI's using SCC, and only using antimicrobial agents on the animals with a high SCC, or with a clinical history and a high probability of contracting an infection during the dry period (Higgins *et al.*, 2017). Animals with a

sufficiently low SCC and a sufficiently low probability of acquiring an IMI, get treated with a teat sealer only, to help prevent any pathogens from entering the teat. Whether or not SDCT has a positive effect compared to BDCT on udder health is reportedly predicated on the efficiency and parameters measured to decide which animals are selected for DCT (Scherpenzeel *et al.*, 2016). Succinctly, this selection-based approach to DCT is intended to mitigate the potential for this type of medicinal usage to act as a driver of antimicrobial resistance, as you are only using antibiotics for the animals that have a need of it. This approach is becoming more and more encouraged on the global market, and even compulsory in some countries, such as the Netherlands (Higgins *et al.*, 2017).

The combination of antibiotics with a teat sealer is not always performed, as the antibiotics are often used alone in a BDCT system. Using a teat sealer in addition to antibiotics is shown to decrease the incidence of clinical mastitis in cattle with a high SCC at drying off, which are defined as high-risk cows. Interestingly, however, the addition of the teat sealer is shown to increase the incidence of coliform mastitis (Bradley *et al.*, 2010)

The most common method of selecting the approach to DCT is the farmers own experience, but the current shift toward a more selective approach is often endorsed by governments, and the WHO (Vilar *et al.*, 2018).

**A comparison of incidence of mastitis between three
Irish dairy farms, and the effect of season on its
occurrence**

Materials and methods

Milk sampling

To perform this comparative study, the data that has been used is based on milk recordings taken from three farms in Ireland. These milk recordings are undertaken by an independent company on a monthly or bi-monthly basis, and the results are given to the farmers. The milk recording results will indicate the milk output of each individual cow, as well as showing the milk solids and fat content of the milk. For every load of milk taken from the farms to the dairy processing companies, a bulk milk recording is taken, which will indicate the total solids and fats, total bacterial count, SCC and total amount of liquid milk taken. However, the bulk milk will not distinguish between animals having a high milk SCC and animals with a low SCC, and so it has no diagnostic value for finding animals with subclinical mastitis. It is however very valuable to map the herds udder health as a whole, as a high BMSCC can identify the existence of a problem.

In the milk recording, the important factor for this study is the SCC of the milk of each individual cow, which allows us to trace the animals with subclinical intramammary infections. In addition to the SCC, it gives the yield, the fat percentage and the protein percentage. The technique of sampling the milk can vary depending on the technician performing the sample, as well as the company processing the samples. The milk sampling technique described below is the common technique used by the commercial milk testing companies in Ireland.

The sampling of the milk for this purpose is taken from a milk jar or milk meter. Each milking claw is connected to a jar or meter which collects the milk as it is extracted from each individual cow. Once the cow is completely milked out, the technician utilises the vacuum system of the machine to agitate the milk that is in the jar. This is to prevent the milk sample coming from a fraction of the milk that may have been sitting in the jar for the longest, and so may be contaminated with sediment or an uneven distribution of milk cells, as this could cause a misleading result. After the milk has been agitated to a “homogenised” mixture, the sample is taken directly from the jar, and sent to a lab for analysis. The process is repeated for each individual cow. The full results are sent to the farmer every month. A specific message is also sent to the farmer containing the details of the 5 cows with the highest SCC for each particular test.

Data collection and herd information

The data used for the Irish dairy herds comes from three farms located in the east of the Republic of Ireland, henceforth known as Farm A, Farm B and Farm C.

Farm A has provided this study with the milk recording data of a herd of 53 cattle that had their milk samples taken in the period of February 2017 until August 2018. Out of these 54, 12 cattle were first lactation heifers in 2018, which means they have contributed no milk recording data for the year of 2017. The milk recording data also excludes animals that were taken out of the herd in the period of milk recording, so there exists a possibility that with a chronically high SCC are not included in the result of the milk recordings used. This farm differs from Farm C in the fact that the milk recording on Farm A is undertaken every month of the lactation.

Farm B contributed the data from a herd of 58 cows. The period of data collection for this herd was December 2017- November 2018. In this herd, the milk recording took place every month, in the same manner as Farm A, with the exception that in the month of June and of September, a milk recording was not performed. The herd comprised of 13 first lactation heifers that calved in the spring of 2018, so these did not contribute to the readings of December 2017. Also, many of the cows are dried off in November, so the milk recording in December only included 32 out of 59 cattle.

The data from Farm C is from a herd of 131 cows. In a different manner to the previous two farms, the recordings were performed every second month in the period March 2017 to September 2018, not every month.

Analysis

The data for each farm was examined in such a way so that the calculated parameters could be found for each individual milk recording. The selected parameters that were calculated was the average SCC, the median SCC and a third parameter based on the SCC average where certain cows were omitted. There was also data regarding protein and fat percentage of milk, but these have not been considered for the purpose of this study. Parity has a significant effect on the udder health of cows (Jingar et al. 2014); however, this has not been considered as one of the variables in the study.

For all of the farms, most noticeably in contrast to the rest of the herd in the case of Farm A, there are some individual cows with a significantly higher SCC than the others. These are

normally animals with clinical mastitis, or with a subclinical infection causing an elevated cell count. In Farm A, these animals were treated using an intramammary infusion, which lowered their SCC significantly in the following milk recording. These cows' readings significantly affected the monthly SCC average, in a way that could be skewing the general picture of the udder health situation on the farm. If we consider them outliers however, the data can be omitted to give a more realistic view of the true herd udder health situation in the context of seasonal influence on the incidence of mastitis. For the sake of clarity, both averages have been included in this paper. Although the median of the data has been calculated, its usefulness to the tracing of SCC trends according to season is limited. Hence, the median where the high scoring cows have been omitted has not been included.

The threshold for omission in this paper was set at 1 million somatic cells/ml milk. This cut-off point was chosen as SCCs over a million can be indicators of IMIs, and the EU regulations would classify anything over 400000/ml as unsuitable for human consumption. In reality, due to mixing the milk in the milk tank, milk from cattle exceeding this limit will regularly reach the market, as long as the BMSCC < 400 000.

Results

For the Irish farms, the hypothesis at the onset of the study was that there would be a visible contrast between the seasons reflected in the SCC results. As the Irish dairy industry is based on keeping the animals on pasture for most of the year, initial assumption of the study was that there would be a significantly lower SCC in the summer months than in the winter months, while the animals were kept in housing. In systems based on year-round indoor keeping, we would expect to see the SCC be higher in the summer months. The specific reasons for this theory were outlined in the literature review part of this paper. This study did not distinguish between the occurrence of clinical mastitis and subclinical mastitis, nor has it placed emphasis on the occurrence of specific conditions, such as summer mastitis. The results are only based on the SCC from milk recordings, and aside from the case of Farm A, the study has not taken history of mastitis treatments into account.

Farm A

The results from this farm are characterised by relatively low numbers compared to the other two Irish farms. As previously mentioned, there are some cows that had very high readings, and in the case of this farm, they were the deviant to the norm. For every one of these cows, the following milk recordings data showed a return to low cell count. Below, the table illustrates the SCC average for each milk recording, sorted by month. It is interesting to note the differences in average SCC if you should exclude cows with a cell count exceeding 10^6 somatic cells/ml milk. If you take the milk recording on the 22.02.2017 as an example, there was one single cow that had a somatic cell count of 5584×10^3 . Once this cow was excluded, the average SCC dropped significantly. In march of the same year, this cow had a SCC of 10 000/ml. The medical records show that this cow was treated with an intramammary infusion of cefalexin, so this was a case of an IMI. This farmer has experienced that some cows will often have high SCCs immediately after calving, and in Ireland, many farmers aim to calve as early in the year as possible. That means that not all high SCCs in this period mean that there was a clinical case of mastitis.

Date:	Avg SCC	Med.Scc	Alt. Avg
22.02.17	261	27	56.5
31.03.17	62.5	23.5	62.5
27.04.17	20.4	11	20.4
30.05.17	167.5	20	36
27.06.17	41	23	41
31.07.17	36.1	24	36.1
28.08.17	48.2	33	48.2
28.09.17	54.4	42	54.4
27.10.17	50.5	43	50.5
21.11.17	141	99	141
26.02.18	101	42	53
30.03.18	144	39.5	64.6
27.04.18	45.6	20	45.6
26.05.18	53.8	17	25.9
26.06.18	154	37.5	68.8
31.07.18	119	19.5	44
28.08.18	44.8	25.5	44.8

Table 1- Farm A parameters. Measured in given numbers x1000

If the numbers are shown in graphical form, it is possible to visualise the trends of SCC according to the date of the milk recording.

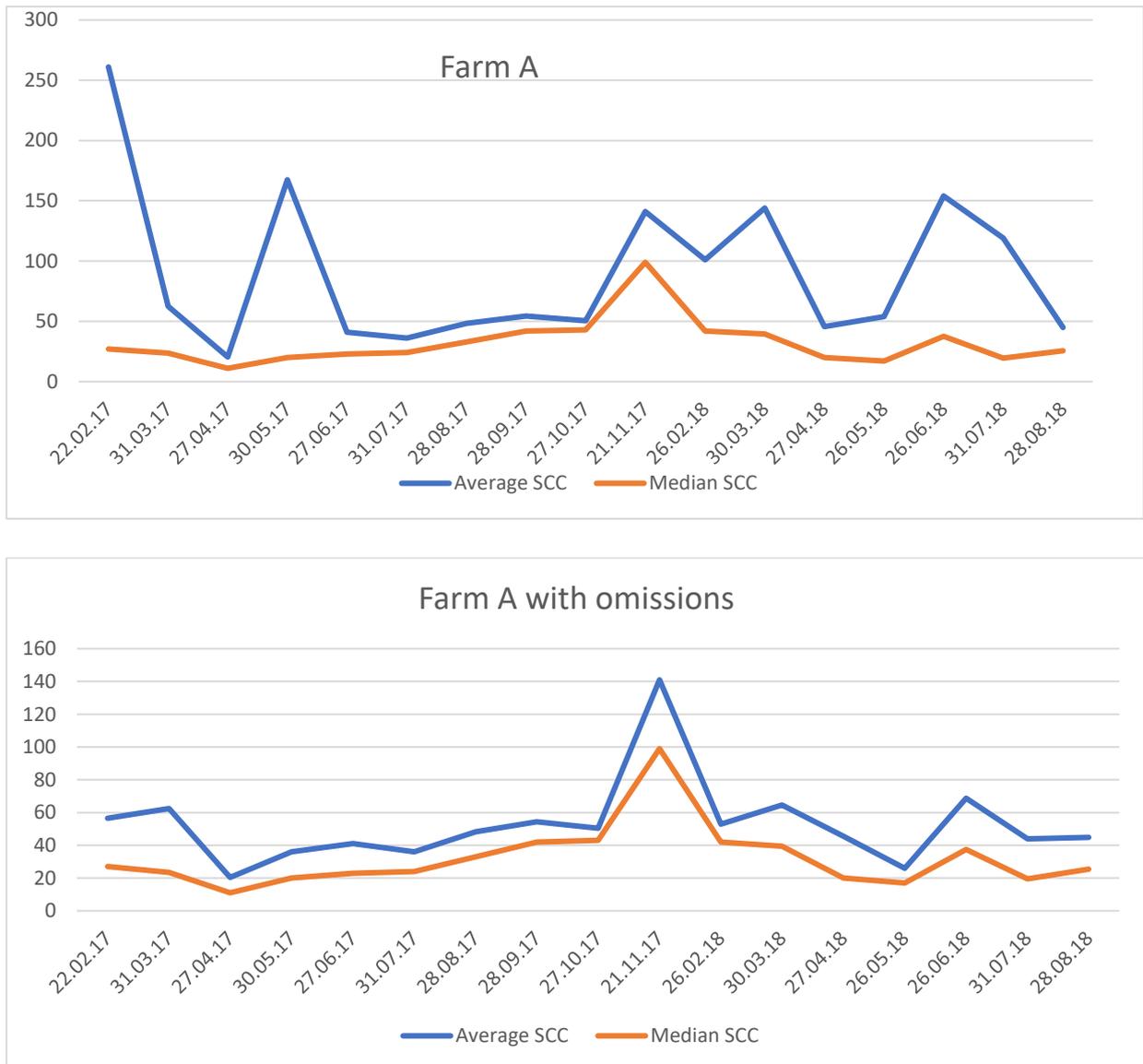


Figure 1 & 2- Farm A SCC trends by month, with and without omitting high scoring cows

Removing the very high SCC cows has a slight effect on the overall trends in the SCC data. There was a significant spike in May 2017, which was caused by one cow with a SCC over 5 million. When this cow was excluded from the results, the graph evens out significantly, and the average SCC shows a notable homogeneity throughout the period covered by the data, with the exception of November 2017. This month there were no cows that had a reading over 1 million/ml. This means that during this month, there was a generally higher SCC throughout the herd. It is worth noting that in November, many cows have already been

dried off by the time of the milk recording, a point that will be expanded upon in the discussion. It is also worth reiterating that in the case of this farm, there was no month where the SCC average of the herd exceeded the limit commonly associated with mastitic milk, even before exclusion of high scoring cattle. This would be a good indication that the farm has a generally good level of udder health.

Farm B

This farm has a different overall situation regarding the SCC of the herd than Farm A. The general SCC count is significantly higher, and there are a lot of cattle in the herd with very high cell counts, even in consecutive milk recordings. Less information is known about this farm than Farm A, so it is unknown if these cows exhibited any clinical signs of mastitis, received any treatments, or if they were so-called “problem cows” in the herd. In a herd with this somatic cell count profile, it may not be productive to exclude cows with a cell count of over a million as this would remove a significant portion of the herd for each recording. It could give a very inaccurate representation of the udder health situation of the herd and it would be harder to consider the high-scorers outliers. However, for the sake of consistency, the data which omits the cows with cell counts above a million have been included in this article.

Date	Avg.SCC	Med. SCC	Alt avg
2017 December	189.0	84.0	139.6
2018 January	214.0	160.5	214.0
2018 February	399.3	67.0	118.2
2018 March	222.3	27.5	98.8
2018 April	133.4	36.5	90.7
2018 May	118.4	29.5	98.7
2018 July	462.0	51.5	115.8
2018 August	544.8	105.0	127.3
2018 October	291.9	58.0	105.7
2018 November	247.8	83.0	128.5

Table 2- Farm B parameters

As is visible on table 2, only one month was unchanged after high SCC cows were omitted, which was January of 2018. This is due to there being very few cattle milking at the time of

recording, whereof two cows were never dried off from the previous lactation. The low number of cows is due to the seasonal calving of Irish herds, and not all cows having calved in January. If the recording was undertaken in early January, this would inevitably lead to very few cows milking, which would lead to a small data set.

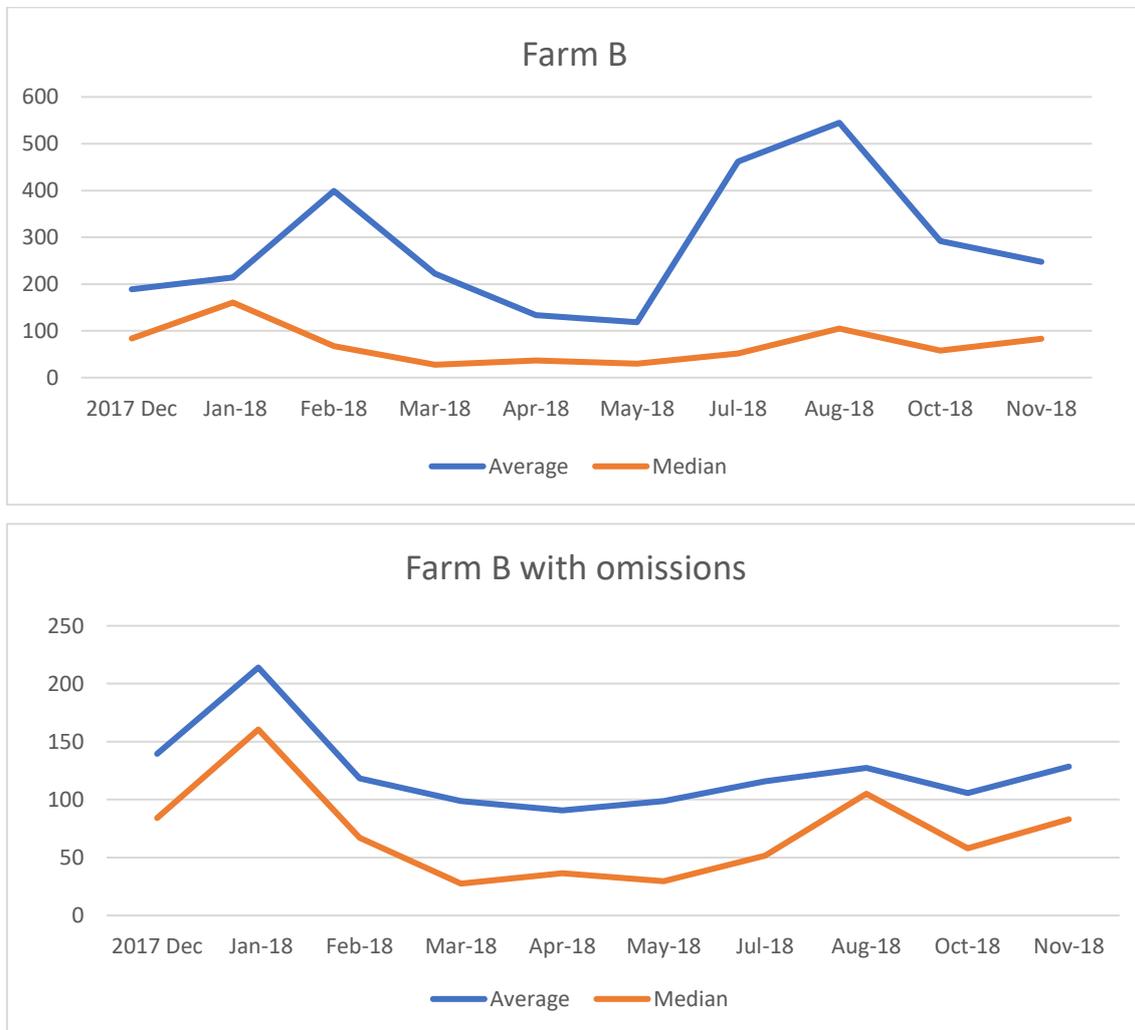


Figure 3 & 4: Farm B SCC trends by month, with and without omitting high scoring cows

As this herd has a large number of cows with a cell count exceeding the threshold of 1 million cells/ml, if we were to remove one of these cows from any given month, it would likely not have much of an impact on the data shown on the graph. This is interesting only in the context of comparison with Farm A, where the removal of one high scoring cow would lower the average of the milk recording considerably. Before excluding any high scoring cows, there is no evidence of the herd SCC being higher in the winter months, on the contrary, it indicates that the worst months for high cell counts was July and August 2018.

If we remove cows exceeding the threshold we set for the purpose of this study, the graph shows a different trend which does seem to indicate a higher tendency of elevated cell counts in the month where the cattle are kept in housing. The high point of January leads to a sharp decrease in the following months until it stabilises at an average SCC of 100 000 cells/ml, before showing signs of increasing in November. In figure 3, August has a higher SCC average than any other month, but in figure 4 it has decreased by 76%. This tells us that August had a very high proportion of cows with either clinical mastitis, or subclinical cases with a very high cell count. It is also interesting to note that the median SCC follows the average in a parallel line, peaking in the same months as the average. This trend is also observed in the two other farms involved in the study. However, this may not be of any particular significance as this median line pertains to the original numbers, including cows with over 1 million in SCC.

This farm also provided each cows average for the previous and the current lactation, as calculated by the milk recording company. The mean value of these averages for the previous lactation was $64,7 \times 10^3$, while on the current lactation it had increased to 175×10^3 . This indicates that the herd SCC count has likely increased by more than 100% from the previous lactation to the lactation period discussed in this paper.

Farm C

For this farm, the herd was considerably larger than for the previous two, with 131 cows tested for the milk recording. This gives a bigger data set to look at. There were numerous cows with a high SCC, but when seen in proportion to the rest of the herd, these results were less frequent.

Date	Average	Median	Alt.Avg
2017 March	179	20	55.8
2017 May	73	21	41.3
2017 June	195.5	26.5	59
2017 September	278	100	129.5
2017 Nov	155.2	92	132.8
2018 Jan	238.2	186	183.7
2018 Mar	356.3	42	71
2018 May	95.5	33	72.1
2018 Jul	77.7	34	65.1
2018 Sep	75.1	41.5	54.6

Table 3- Farm C parameters

As the period studied from this farms' milk recording results started in March, the majority of the cows in the herd had already calved, which means more data was available from the onset of studied period. As previously stated, the month of January will have fewer numbers in the data set, but for this farm the large herd size ensured that there were still 56 recorded milk samples available.

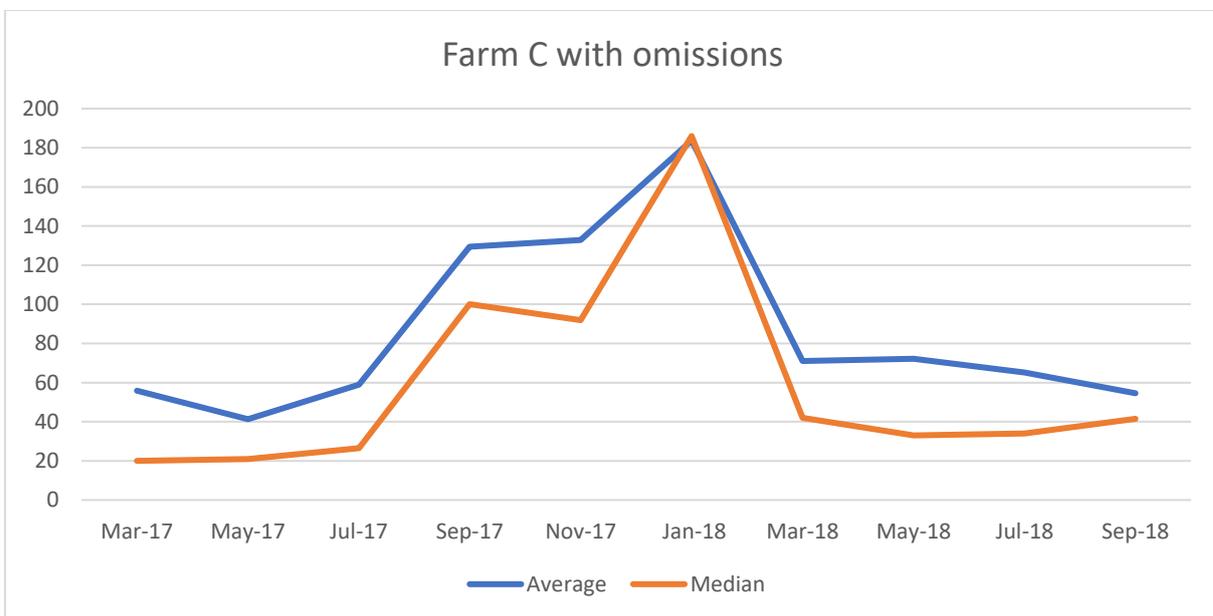
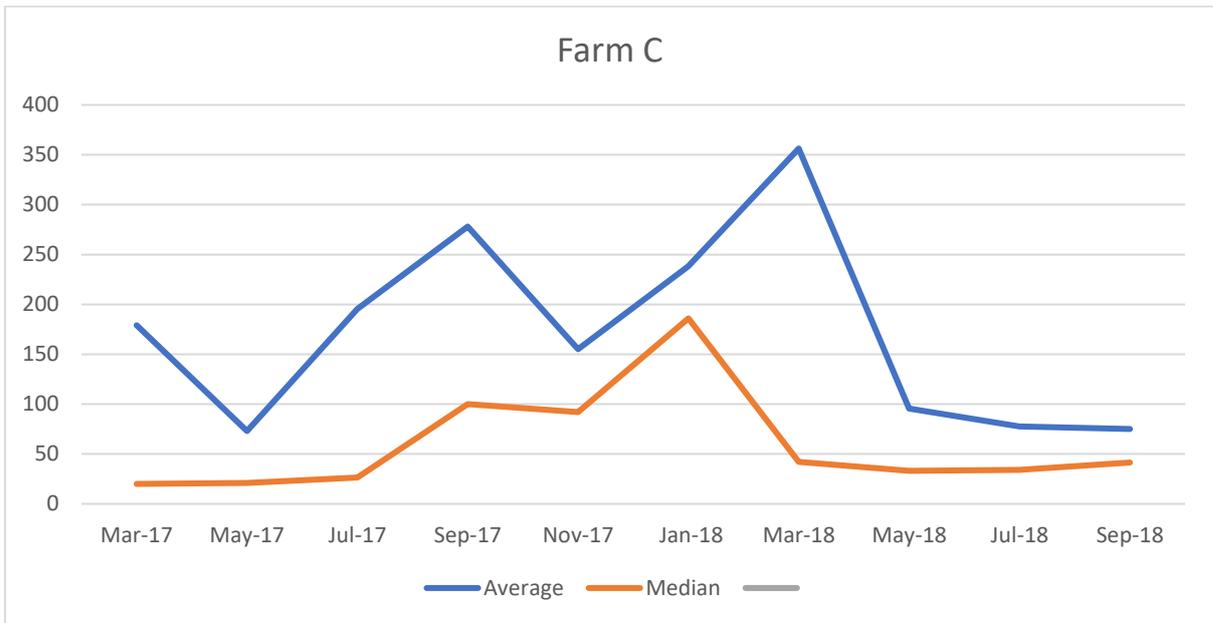


Figure 5 & 6: Farm B SCC trends by month, with and without omitting high scoring cows

The graphical illustration of the results in figure 5 is twin peaked, with the highest scoring months being September of 2017 and March 2018. Due to the bi-monthly milk recording

structure on this farm, the transition from month to month will likely be more dramatic than if these milk recordings had been performed every month. In the same manner as for the previous farms, the spread of the high points of the graphical curve does not appear to follow the expected curve favouring the months of winter housing as a period characterised as having a higher average SCC. In the case of Farm C, the act of excluding high scoring cows concentrates the peak of the curve between September 2017 to January 2018, with all recording data showing mean values of below 200 000/ml milk.

It is possible to note the continuing trend throughout all the three farms of there being a tendency for the data, with no animals excluded, having more than one SCC spike in the milk recording period. When excluding all the very high SCC cows, the resulting peak on the curve seems to be concentrated within a period of the year conceivably fitting with the initial hypothesis of the study. Whether this correlation is entirely artificial or not will be examined further in the discussion below.

Discussion

This study aimed to map out the average SCC to examine the influence season has on herd udder health. The study focused solely on the SCC data provided from the three farms, and did not attempt to distinguish between the different forms of mastitis, such as the clinical and subclinical subtypes.

The question is whether or not the results gives any significant credence to the idea that in the Irish system of outdoor keeping for the majority of the year, and housing only in the winter months will lead to a clear tendency of an elevated somatic cell count in the months of housing. The cows in Ireland are brought inside to the barn in autumn/winter according to the weather conditions in a year, and there is no definite date consistently adhered to in regards to taking the animals off pasture. For the year of 2017, Farm A reported to have brought the cows in by night at the end of October, and in this transition period they are kept grazing during the daytime. Subsequently, they are brought in full time in mid-November. The cattle are let out by day in early March, and they are on pasture full time by the end of that month. Given that the three farms discussed in this study are all situated in the same general area of the Eastern Republic of Ireland, they would be affected by the same weather conditions in the period of interest. This makes it reasonable to assume that Farm B and Farm C followed a similar procedure when bringing cows in or letting them out. This gives

us a general frame of interest with a relatively clear separation between the months of pasture and the months of housing.

The data at first glance does not yield a picture that gives a clear seasonal pattern of high SCC. If you look at figures 1, 3 and 5, there is a seemingly arbitrary spread of the graphical peaks on the curve, with seemingly no regard to the season the milk recording was performed. An example of this is figure 1, where the peaks are located in the months of May and November 2017, as well as March and June 2018. In figure 3, there is a peak in February, but the highest scoring months are July and August. In figure 5, the highest numbers are found in September 2017 and March 2018. If taking no regard to reasoning behind the elevated SCC according to the time of year, there is very little to indicate that the season affects the herd udder health of these in the way that was expected.

One thing that all the farms had in common, however, was the dramatic change in the SCC average in the summer months after removing cows exceeding the set threshold of a million somatic cells/ml milk. In every case, even in the case of Farm B where the summer months recorded the highest SCC average, the removing of high scoring cattle resulted in a significant reduction of the SCC average of these periods. This indicates that the summer months had a higher proportion of very high scoring cows compared to the months of housing. There can be many reasons for this, one of which could possibly be summer mastitis. This is a form of mastitis, often caused by for example *Trueperella pyogenes*, as well as other previously mentioned pathogenic agents. It can be spread by flies, and is named summer mastitis due to the season of occurrence, and occurs mainly in animals kept on pasture (Berry & Booth, 1999). As this issue may cause an elevated SCC, it is possible that there was a high number of cows affected in the time of milk recording, which would drive the herd average SCC up. Since these would be clinically affected cows, they would likely exceed the threshold of 1 million somatic cells/ml, and hence would be eligible to be removed by the parameters of this study. This would mean that the degree of contrast between before and after removing high scoring cattle would be higher in the summer months, as the winter months are characterised by a more herd-wide elevation of SCC that is below the 1 million cells/ml limit. Without the medical records of the farms, however, it is impossible to confirm the incidence of summer mastitis in the relevant period.

In the case of Farm A, there was a peak on the curve in May 2017. In the farmers own experience, this is a period of the year he often sees elevated SCC in the herd. According to

the farmer, SCC of this farm increases in this period due to the start of heat signs. When cows are in heat, they start mounting other cows or bullocks on pasture. As this would expose the udders to the backside of other cattle, it is a feasible situation that this could lead to an elevated average SCC in the herd, assuming this behaviour is observed throughout many members of the herd. This could also play a part in the elevated SCC average observed for Farm C in the month of March.

Once the cows measuring a SCC over the threshold set for this study is removed, the data is changed significantly. From that data, the herd average SCC more closely resembles the expected udder health situation as regards to the season, with the peaks of the curve occurring in the winter months of the year. In the case of Farm A, the highest average SCC counts can be seen in November of 2017, with the rest of the curve appearing relatively stable, with values mostly in the range of 40-60 000 SCC/ml. This solitary peak can in itself indicate circumstances not adhering to the underlying assumption that the season had any influence on the value, as in November they also spend a significant amount of time on pasture. In the case of Farm B, figure 4 shows a similar situation with a solitary peak in January, followed by a lowering of the values for the rest of the milk recording period. Finally, for Farm C, figure 6 indicates a situation more closely adhering to the hypothesised distribution of SCC averages, with the entire period between September 2017 to November 2017 indicating a steady rise in SCC averages, finally peaking in January while the animals are housed. If this could be considered an accurate representation of the herd udder health situation, it is possible to imagine that the increase of SCC in the autumn of 2017 can be caused by weather conditions increasing the bacterial load on the udder. This bacterial load could be due to wet mud created by consistent rain on pasture, which could affect the likelihood of subclinical or clinical mastitis due to cows laying down while grazing.

The difficulty of casting any significant reflection of the udder health situation of a herd in this system of animal husbandry is that the dry period of the cows overlaps with the housing period. The drying off of cows generally starts in November, and in most cases the majority of the animals are dry in the entirety of the month of December. This means that there is no data available for this period of the year. Most of the cows do not calve until the latter half of January, and in many farms the calving would not start in earnest until early February. This means that the data available for the winter months is characterised by smaller data sets, which could significantly affect the results.

Conclusion

With a sample size this small, there is a possibility of all three farms exhibiting abnormal trends in regard to monthly SCC, which does not reflect accurately on the entire Irish dairy industry. Area, weather conditions of a given year, the average parity of the herd, spread of specific contagious or environmental pathogens and other known predisposing factors all have a significant influence on the SCC, and all can be different from year to year. To have a truly indicative result on the seasonal influence on mastitis, more data would be needed, ideally from farms over a larger area and a longer period.

Without any form of exclusion of data from the study, there is no indication of the data matching up to the assumptions made about the incidence of mastitis in each season. As previously discussed, the high SCC scores was seen to occur at any time of the year, also in the summer, where there were some very high average SCC scores relative to the respective herds in two out of the three farms. Only by excluding cows with exceptionally high cell counts, in comparison to the rest of the herd, would the peaks on the graphical curve be concentrated to a certain time of year. The legitimacy of the data after removing these so-called outliers can still be called into question, and still it does not provide any more conclusive evidence of the claim that the herd SCC average will be consistently higher in the winter.

As it stands, this study cannot provide evidence of a higher degree of udder health issues in the winter period. It can, however, indicate a trend in the data that can be attributed to the different seasonal issues experienced on the farms. The summer period when the cows were on pasture had numerous animals with high cell counts, with a higher proportion exceeding 1 million somatic cells/ml than in the winter period. This may indicate a higher susceptibility to severe IMIs during the spring and summer months when they are kept outside. The data from the housing period showed a more pronounced tendency to retain a higher herd SCC average after removing these cows, which may give the impression that the baseline SCC is higher in the months of keeping the cows in housing.

In short, it can appear that the highest herd average SCC numbers are found in the spring and summer, but a higher proportion of the herd will have an elevated SCC during the winter period.

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Appendix A

Farm A

CowID	Lact nr	calv.date	DIM	Avg SCD	22.02.17	31.03.17	27.04.17	30.05.17	27.06.17	31.07.17	28.08.17	28.09.17	27.10.17	21.11.17	26.02.18	30.03.18	27.04.18	26.05.18	26.06.18	31.07.18	28.08.18		
1	6	15.05.17	207	62				81	15	56	35	43	69	505					4333	11	32		
131	6	09.02.17	302	62	16	108		10	20	16	24	21	219	67	137				219	2441	159		
133	6	16.04.17	236	37				63	22	29	26	19	41	59	78			20	24	46	62	33	
503	5	18.04.17	257	21				15	11	15	20	25	22	26	53	59	55	16	14	23	38	30	
524	4	17.02.17	305	47	62	73		19	26	36	33	47	85	47	95		38	21	17	29	20	29	
525	3	10.05.17	305	28	23	27		10	20	54	38	50	31	47	51	42	40	67	36	57	41	65	
526	3	07.03.16	560	25	36	10		5	17	21	20	40	84	95		20	21	5	14	15	15	15	
527	4	09.02.17	302	24	16	13		10	11	21	14	19	49	39	248		70	12	9	20	18	21	
535	4	02.06.17	171	34						21	13	27	34	48	135	86	73	142	93	90	72	345	
537	5	10.02.17	294	23	27	8		7	18	16	16	33	35	40	131		187	7	13	20	19	19	
566	2	30.01.17	312	17		13		12	23	31	13	22	24	15	42			12	7				
577	3	02.02.17	305	31	17	8		11	13	23	25	55	99	103	116			17	15	24	15	25	
579	3	29.04.17	309	14				7	8	6	16	30	16	38				30	6	44	9	11	
586	2	18.02.16	648	49	52	79		35	225	115	109	388	180	81					18	24	24	45	
588	3	06.03.17	277	22		27		10	24	21	13	16	26	20	68			25	16	31	13	19	
593	3	06.02.17	318	52	5584	10		7	26	34	25	111	52	28	109	20	11	11	18	53	34	39	
604	2	30.01.17	325	28	35	13		14	14	29	27	34	40	36	84		20	14	14	30	138	17	
613	2	13.01.17	342	56	13	30		42	87	47	68	74	111	71	120		43	20	18	31	17	70	
617	2	24.02.17	287	53		154		73	19	53	89	49	34	26	73		1952	45	1393	57	55	35	
619	2	12.02.17	299	32	41	13		4	13	25	19	41	57	69	470			16	29	22	10	26	
622	2	28.01.17	327	29	16	20		9	17	16	33	25	43	88	150	37	88	18	10	168	54	13	
623	2	18.01.17	337	25	14	19		6	17	18	18	24	59	54	164	45	27	17	10	28	17	33	
625	2	29.01.17	313	49	20	33		11	50	36	196	91	37	76	116			22	15	74	27	79	
631	2	07.04.17	258	14				8	14	16	13	19	14	14	17		14	7	4	39	9	10	
644	1	03.02.17	296	26	98	35		11	31	23	20	18	19	28									
648	1	01.02.17	310	20	18	12		9	32	19	16	26	22	15	52			20	16	30	19	14	
653	1	29.01.17	313	36	31	74		13	34	24	19	61	42	35	99				30	14	10	9	
654	1	27.01.17	328	15	11	18		10	14	10	13	23	23	12	28		31	24	9	40	10	15	
663	1	15.02.17	309	47	64	34		11	33	407	48	29	52	19	107	34	59	14	15	31	17	22	
664	1	25.01.17	330	66	66	86		32	36	84	53	87	77	64	121	42	47	15	14	26	12	23	
666	1	26.06.17	165	83							37	103	31	41	157								
667	1	04.02.17	295	34	225	19		12	120	24	17	21	50	21		27	20	25	15	43	12	17	
668	1	12.02.17	299	43	180	375		30	67	19	14	18	32	20	53		183	24	12	34	11	11	
671	1	14.03.17	282	53		48		27	47	55	43	68	84	49	88	35	39	39	58	63	70	80	
677	1	17.03.17	279	63		44		33	37	94	51	52	48	52	452	31	60	8	13	35	17	24	
682	1	26.02.17	285	29		27		21	14	35	16	28	29	43	80			19	11	15	42	33	
689		2018													94	23	39	20	106	20	52		
690		2018																184	83	192	116	211	
694		2018													49	22	17	19	31	18	45		
695		2018													44	24	25	22	32	15	20		
696		2018														63	62	54	182	321	113		
697		2018													85	24	39	77	160	100	54		
703		2018													96	40	10	16	41	14	14		
704		2018													19	29	15	103	38	21	17		
706		2018													20	89	12	26	28	12	18		
709		2018													232	53	235	30	62	38	44		
713		2018													48	23	21	19	43	14	11		
721		2018													21	16	4	9	27	9	13		
722	6	06.02.17	305	115	342	418		106	5164	40	25	35	39	50	74			57	28	670	1430	47	
739	6	01.02.17	323	36	11	23		10	21	19	16	33	63	191	635	1218	28	22	20	40	45	19	
758	7	23.02.17	301	52		223		12	29	10	53	34	62	162	196			608	619	91	175	385	89
1326	2	11.02.17	313	30	27	18		12	49	35	24	40	74	23	42			1038	40	20	34	27	36
1345	2	04.02.17	320	26	8	17		24	31	26	71	20	35	15	63	34	29	12	14	37	23	23	

Appendix B

Farm B

Animal	Lactating	Avg Previous Lac	Avg Current Lac	2017 D	Jan-18	2018	2019	2020	2021	Jul-18	2022	2023	2024
2	7	33	36	60		13	8	15	24	48	105	58	162
18	8	132	310	535					86	431	2535	54	433
27	7	71	24	72			17	14	23	16	81	23	30
29	6	26	289	415	431	255	334	358	206	181	49	192	147
31	6	682	1507	1719		7830	201	255	1242	1739	2705	6447	1757
37	7	35	54	83		114	10	15	12	117	125	166	154
46	6	136	180		82	841	275	133	77	305	99	93	95
55	5	23	119	63	76	65	126	287	265	323	3758	268	409
58	5	28	72	141	147	93	145	184	78	177	486	148	158
61	5	30	221	85					11	116	2212	326	573
63	5	55	32				17	26	26	15	51	60	71
64	5	84	163	992	374	336	262	129	92	75	159	10	58
71	6	140	165	166			50	113	410	388	289	191	67
107	13	92	1769	150					439	1927	4439	2604	1770
126	11	112	1306			1122	880	573	793	984	4452	2064	2088
143	3	36	209	37		70	3261	77	151	47	80	607	607
158	2	18	46			18	47	15	89	60	112	82	31
159	11	208	583	153			334	96	175	1569	1879	756	1821
165	2	42	63			13	77	40	31	124	188	71	118
167	2	24	28	14					28	14	30	30	48
169	2	35	29			18	8	11	8	90	269	22	73
177	2	36	37			26	28	34	24	23	50	62	92
186	2	28	11			11	18	9	7	6	14	16	18
207	2	22	23			20	8	9	12	19	137	36	53
213	1		92			204	38	44	61	134	124	81	191
214	1		30			245	9	20	13	6	82	39	66
216	2	28	277			226	55	99	158	1288	1158	440	272
219	2	31	29			25	8	9	15	55	70	58	79
220	2	35	21				16	18	13	12	28	26	49
222	1		71				29	55	41	147	183	59	85
223	2	31	27				16	14	9	38	92	15	109
224	1		21			58	21	15	11	12	31	16	28
230	2	65	11	76				9	6	11	18	11	12
262	1					52	411	10	18	11	260	32	33
264	1		49			44	28	35	26	244	105	32	36
270	1		24			72	10	21	18	33	33	19	20
272	1		313			255	2368	238	367	6533	363	27	27
277	1		212				408	175	62	7723	220	39	66
279	1		28				15	37	16	29	30	16	101
281	1		24				13	94	16	25	41	18	14
284	1		19			67	14	14	13	14	29	11	18
295	1		44			27	17	25	23	28	288	99	69
352	4	58	45	152				56	10	32	75	50	125
353	5	29	273	95			64	76	486	371	1204	256	422
355	5	29	22	152		21	3	8	4	69	65	83	72
356	5	46	39	114				28	51	19	26	59	81
368	4	17	17	24		27	9	9	7	6	126	14	40
374	5	44	143	139		68	6	153	206	246	540	319	324
1001	4	157	161	167				36	168	153	327	163	354
1003	3	41	120	153	174	137	78	147	79	230	331	140	158
1009	4	22	31	31				54	6	11	60	44	87
1022	4	29	45	41					38	26	45	23	179
1062	4	19	63	40			12	2310	87	15	53	60	34
1069	3	18	26	30				47	16	11	67	24	21
1086	3	22	62	34				654	81	20	15	33	109
1090	3	16	322	67					312	378	1148	194	131
60173	2	34	35	36			27	19	116	14	49	34	46
80159	3	13	11	13				13	7	6	11	11	24

Appendix C

Farm C

Animal	Lactatio	Avg Previous Lac	Avg Current Lact	Mar-17	May 17	Jul-17	Sep-17	Nov 17	Jan-18	Mar 18	May 18	Jul-18	Sep 18
489	10	126	572	661	290	468	96			369	695	728	
561	10	46	178		60	603	155						
607	9	93	33		25	17	87						
625	9	317	3485			5016	2421						
742	9	700	47	4250	1092	668	564	96		47			
745	9	30	90	20	16	31	84			119	42	139	94
831	8	62	62	20	39	37	179	177					
834	7	77	102	1073	7	7	63	606	346	171			
934	6	31	60	43	8	33	103	116	343				
937	6	51	60			13	131	61	66			21	173
956	6	29	86	13	42	26		50			150	155	27
958	4	106	67			64	82	28	71	129			
965	5	63	40	43	18	41	271	66	115			40	40
970	6	25	121		19	12	71				502	132	27
980	5	48	32	39	13	29	71						
981	5	59	118		15	31	104	265	1793				
986	5	98	28	21	180	297	356			35	55	16	21
989	6	96	37	681	25	19	101	247		20	29	23	140
995	6	119	86	50	48	86	199	229	300	3907	29	7	68
1000	6	607	437		599	8048	72	391		210	895	589	329
1003	5	47	93	103	48		86	49	92	197			
1005	5	167	214		128	138	217	77	441		171	419	136
1006	6	20	20	9	12	19	84						
1010	5	32	22	7	14	26	88						
1011	6	328	328			88	972	382	354				
1014	5	70	149		31	47	118	847	310	176	165	184	
1017	6	35	31	9	9	25	327	81		56	20	34	25
1018	6	62	48	34	149	107	430	4			31	44	82
1022	5	35	31	6	12	21	78	39	183				
1027	6	21	21		11	18	45						
1033	6	82	20	2860	14	55	48	7	398		28	14	
1036	5	27	29	8	8	15	146	107		67	21	13	39
1043	6	54	6	98	17	24	68	163		85	67	103	28
1045	6	16	407	6	12	13	71			100	98	1384	2018
1055	5	55	33	11	10	71	80	109	414	26	22		65
1067	4	265	241	310	35	3476	181	95	304				
1121	5	31	40		7	10	29	73	195			25	63
1122	5	28	109	6	12	12	41	47	282	253	234	61	39
1124	4	16	27	10	10	16	40			27	20	27	38
1130	4	70	36	41	33	44	168	173		26	17	54	72
1133	5	19	36	11	9	9	160			9	18	104	95
1140	5	28	35	7	12	23	180	47		14	40	35	73
1151	5	21	26	13	6	10	88	60		7	41	51	31
1159	5	30	15	18	7	16	135	84		5	8	31	42
1167	5	23	85	15	8	19	33	33	53			61	118
1168	4	122	62	47	102	66	153		130	27	38	123	55
1171	5	143	25	2309	74	33	129	83		11	35	17	56
1195	4	40	29	12	23	61	104	34	64		29	16	54
1200	4	67	70	39	33	58	272			77	65	204	23
1215	4	46	74	9	30	27	117	79		116	62	74	57
1220	4	56	144		47	26	46	126	81			193	107
1229	4	24	24	11	10	14	54	91		12	20	79	19

1236	4	86	86			36	69	112	197					
1239	4	54	72	190	13	14	141	97	86	69	54	76	77	
1242	4	42	18	14	6	98	40	82	216			13	25	
1243	4	117	59	10	1336	20	229	362		44	42	79	84	
1247	4	37	9	10		6	99	34	94		7	4	27	
1249	4	84	57	194	19	18	258	111	187		130	41	35	
1256	4	33	36		39	12	79			20	24	53	65	
1259	3	32	224			447	98	1042	55					
1262	4	29	48		5	10	44	54	170	31	192	17	51	
1268	3	59	35	14	54	65	123	120		25	48	19	67	
1269	4	32	18	5	35	29	46	147		15	15	15	30	
1274	4	94	90	11	4	17	1871	307	1628	105	38	273	59	
1275	4	17	61	11	12	12	30	34		2686	33	8	20	
1278	4	66	41	12	6	52	203	367	310		47	19	79	
1283	4	26	26		4	15	87	82		26	36	10	46	
1285	4	30	26	24	10	18	192			14	37	35		
1288	4	39	36	13	29	19	129	102		35	51	26	36	
1289	4	111	46	116	105	80	154			150	28	27	40	
1290	4	39	18	12	8	64	64	77	111			15	22	
1291	4	15	14	6	7	11	38	47		7	13	25	18	
1293	4	37	20	10	62	8	55	96	102		19	6	19	
1300	3	47	34	41	117	22	42	54		35	30	47	26	
1301	4	29	23	20	15	14	172			21	19	14	51	
1326	3	64	40	27	27	39	350	112		14	82	69	33	
1327	3	72	37	27	52	64	205	105		26	53	35	41	
1329	3	26	85	11	6	32	58	92		49	305	32	108	
1339	2	77	72		25	39	136	117	164	54				
1341	1		56	70	9	51	82	57	96					
1346	3	19	48	7	14	7	68	50		50	42	66	37	
1354	3	54	55		43	12	102	49	185			90	34	
1356	3	19	55	12	29	11	34		211	39	33	25	73	
1365	3	56	82	30	21	27	180	178		54	73	88	128	
1372	3	38	208	5	277	30	49			8380	82	59	46	
1375	3	24	32		8	18	41	52		72	19	27	29	
1379	3	31	58	12	24	44	71		41	55	52	66	82	
1380	3	51	113		68	14	136			207	122	75	86	
1382	3	56	20	20	15	26	147	91	283		20	10	42	
1384	3	19	46	9	9	9	168		218	39	43	31	19	
1387	3	28	24	16	9	21	80	73		43	33	11	20	
1397	3	47	28		10	30	133	92	62		18	29	40	
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1405	3	30	84	32	12	17	89	43		63	241	153	21	
1406	3	32	32	37	11	16	57	93						
1409	2	129	206						206					
1412	3	24	34		10	13	45	60		42	19	40	40	
1415	3	140	100		32	21	4175	76	252		2345	9	48	
1419	3	98	84	272	66	37	140			164	100	95	32	
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1426	3	32	34	9	50	39	61		33	18	71	64	16	
1427	3	91	140	13	70	331	343	59		1844	129	41	39	
1432	3	104	18		10	60	97	606	337		28	6	34	
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1448	2	84	71	56	24	187	194			580	33	19		
1449	2	144	44	1123	21	31	115	431	248		17	116		
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1455	2	48	19		67	13	156	42		26	18	7	37	
1459	2	64	70	20	86	39	136	117		38	114	61	93	
1491	2	53	24	19	44	48	74	146		21	25	26	24	
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1466	2	90	37		50	56	67	343		35	23	14	160	
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1482	2	55	152	54	35	28	178			1382	88	87	51	
1486	2	1283	30		1560	1163	1182	1264		42	30	20	31	
1488	2	103	71	104	75	56	253			204	53	56	42	
1491	2	163	53		72	199	268	186		183	38	25	47	
1520	1		39		13	36	58	38	38	129	32	30		
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1523	2	149	59		134	110	228	157	139		64	45	73	
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1589	2	36	26	11	17	254	36		55	13	23	27	26	
1591	2	131	15	158	90	114	181		12	20	14	14	15	
1592	2	37	32	31	22	69	42		58	12	15	99	32	