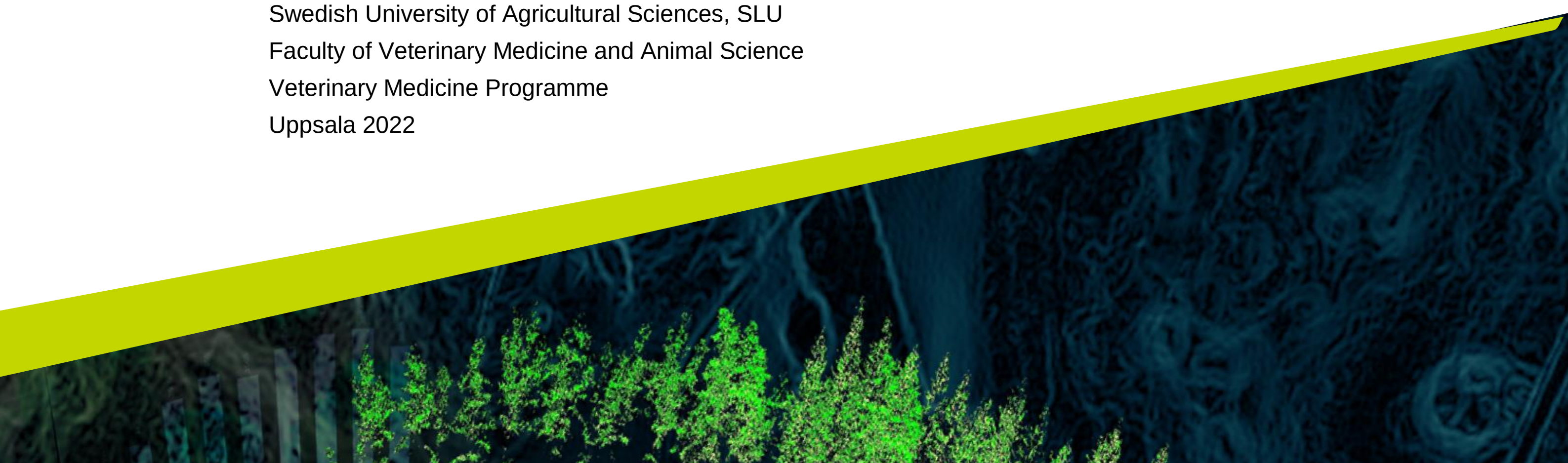
Pasture related characteristics and management strategies associated with udder health in farms with an automatic milking system

– impact on somatic cell count and milking frequency

Betesegenskaper och skötselrutiner associerade med juverhälsa på gårdar med ett automatiskt mjölkningssystem
- påverkan på celltal och mjölkningsfrekvens

Emma Laufors

Independent project • 30 credits
Swedish University of Agricultural Sciences, SLU
Faculty of Veterinary Medicine and Animal Science
Veterinary Medicine Programme
Uppsala 2022



Pasture related characteristics and management strategies associated with udder health in farms with an automatic milking system – impact on somatic cell count and milking frequency

Betesegenskaper och skötselrutiner associerade med juverhälsa på gårdar med ett automatiskt mjölkningssystem - påverkan på celltal och mjölkningsfrekvens

Emma Laufors

Supervisor:	**Lena-Mari Tamminen, Swedish University of Agricultural Sciences, Department of Clinical Sciences; Veterinary Epidemiology Unit**
Examiner:	Ann Nyman, Växa Sverige/Swedish University of Agricultural Sciences, Department of Clinical Sciences; Veterinary Epidemiology Unit

Credits:	30 credits
Level:	A2E
Course title:	Independent project in Veterinary Medicine
Course code:	EX0869
Programme/education:	Veterinary Medicine Programme
Course coordinating dept:	Department of Clinical Sciences
Place of publication:	Uppsala
Year of publication:	2022
Keywords:	Somatic cell count, milking interval, automatic milking system, udder health, heat stress, pasture strategies, preventative measures

Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science
Department of Clinical Sciences
Veterinary Epidemiology Unit

Publishing and archiving

Approved students' theses at SLU are published electronically. As a student, you have the copyright to your own work and need to approve the electronic publishing. If you check the box for **YES**, the full text (pdf file) and metadata will be visible and searchable online. If you check the box for **NO**, only the metadata and the abstract will be visible and searchable online. Nevertheless, when the document is uploaded it will still be archived as a digital file.

If you are more than one author, you all need to agree on a decision. Read about SLU's publishing agreement here: https://www.slu.se/en/subweb/library/publish-and-analyse/register-and-publish/agreement-for-publishing/.

☒ YES, I/we hereby give permission to publish the present thesis in accordance with the SLU agreement regarding the transfer of the right to publish a work.

☐ NO, I/we do not give permission to publish the present work. The work will still be archived and its metadata and abstract will be visible and searchable.

Abstract

Udder health plays a central role in the dairy industry and poor udder health can entail both negative economic and animal welfare consequences as well as increased antimicrobial use. The somatic cell count (SCC, a commonly used measurement of udder health) has been observed to increase during the summer season both in Sweden and in other countries. One contributing factor to this is believed to be heat stress which, among other things, influences the immune function of dairy cattle and other animals. With increasing temperatures and a higher vulnerability in high producing dairy cows there is a need to try to prevent the heat stress during warmer periods and to keep up a good udder health.

The aim of the present study was to investigate the impact of warmer periods on SCC and milking frequency on farms with an automatic milking system (AMS) as well as explore the different pasture characteristics and management strategies used on these farms. In addition, the effect of these strategies in maintaining the SCC during warmer periods and grazing season is investigated.

The study is based on 26 phone interviews with farmers that has an automatic milking system (AMS). The interview included questions about their pasture, feed, udder health, milking system focusing on their experiences during the summer months. The selection of farms for the interviews were based on data from 2017 to 2019 from the Swedish cattle database (SCD) and included farms that have an increase in SCC in the summer and those that are less affected. The answers were categorized into different groups and mainly analysed considering the mean proportional difference in SCC between winter and summer from 2017-2019, mean summer SCC 2017-2019 and milking interval 2021. They were analysed using the statistical tests Mann Whitney test and Kruskal-Wallis.

A significant seasonal difference between winter and summer was found regarding both SCC and milking frequency, while the SCC increased the milking interval decreased during the summer. Limiting water to only the barn was not beneficial to maintain the same milking interval during summer. The udder health on farms where cows had a low intake of roughage on pasture and no access to shade on pasture was less impacted by the summer season, possibly due to these cows spending more time inside the barn. Similarly, cows with limited access to pasture appeared to have a higher milking interval compared to those with unlimited access to pasture.

It is hard to draw any conclusions from this study, other than on the included farms the SCC increased, and the milking frequency decreased during the summer compared to the winter. By studying the SCC and milking frequency of the participating farms some were successful in maintaining them during summer. Which shows that it is possible to maintain the udder health during the summer combined with an AMS and grazing. Further research is needed looking at characteristics and management strategies both inside the barn and on pasture to completely understand why there is a seasonal pattern with a higher SCC during summer.

Keywords: Somatic cell count, milking interval, automatic milking system, udder health, heat stress, pasture strategies, preventative measures

Sammanfattning

Mjölkkornas juverhälsa spelar en central roll inom mjölkindustrin och en försämrad juverhälsa ger en försämrad mjölkavkastning vilket ger negativa ekonomiska konsekvenser, men även risk för försämrad djurvälfärd och ökad antibiotikaanvändning. En höjning av mjölkens somatiska celltal (ett mått på juverhälsa som visar på juverinflammation) har i tidigare studier observerats under sommarmånaderna, både i Sverige och internationellt. En bidragande faktor till detta tros vara värmestress, som bland annat påverkar mjölkkornas immunförsvar. Med ökande temperaturer och en högre känslighet hos de högproducerande mjölkkorna finns det ett behov av att försöka förebygga värmestressen under varmare perioder för att upprätthålla celltalsnivån.

Syftet med den här studien var att undersöka varmare perioder påverkan på celltal och mjölkningsfrekvens på gårdar med ett automatiskt mjölkningssystem (AMS). Syftet var även att utforska olika beteskännetecken och skötselstrategier på dessa gårdar och se hur dessa påverkar möjligheten att upprätthålla celltalsnivån under varmare perioder och betessäsongen.

Studien är baserad på 26 telefonintervjuer med lantbrukare som har ett automatiskt mjölkningssystem (AMS). Intervjun inkluderade frågor om deras beten, foder, juverhälsa, mjölkningssystem med mera med fokus på lantbrukarnas erfarenheter och rutiner under sommarmånaderna. Mjölkgårdarna valdes ut baserat på data från 2017–2019 från Växas kodatabas och inkluderade gårdar som ökade i celltal från vinter till sommar och de som inte påverkades lika mycket. Svaren kategoriserades i olika grupper och analyserade med avseende på fram för allt medelvärdet av den proportionella differensen av vinter- och sommarcelltalet, medelvärdet av sommarcelltalet 2017–2019 samt mjölkningsfrekvens 2021. För att undersöka om det fanns några samband mellan juverhälsomåtten och mjölkningsfrekvens och svaren i enkäten användes de statistiska testen Mann-Whitney test samt Kruskal-Wallis-test.

En signifikant skillnad mellan vinter och sommar fanns med avseende på både celltal och mjölkningsfrekvens där celltalet ökade medan mjölkningsfrekvensen minskade under sommaren. Att begränsa vattentillgången för korna till enbart inomhus visade sig inte ha någon effekt på mjölkningsfrekvensen. Kor med fri tillgång till betet hade lägre mjölkningsfrekvens jämfört med de som hade begränsad tid. Juverhälsan på gårdar som hade ett lågt grovfoderintag på betet påverkades mindre på sommaren, vilket kan bero på att de korna eventuellt spenderade mindre tid på bete och mer inne i ladugården.

Det är svårt att dra några slutsatser från studien, annat än att celltalet ökade och mjölkningsfrekvensen minskade på sommaren på de inkluderande gårdarna. Genom att studera celltalet och mjölkningsfrekvensen på de inkluderade gårdarna går det att se att vissa var framgångsrika att bibehålla de under sommaren. Vidare forskning behövs för att titta närmre på egenskaper och skötselrutiner både inne i ladugården och på betet för att helt förstå varför det finns ett säsongsbundet mönster med ett högre celltal på sommaren.

Nyckelord: Somatiskt celltal, mjölkningsintervall, automatiskt mjölkningssystem, juverhälsa, värmestress, betesstrategier, förebyggande åtgärder

Table of contents

1. Introduction

The climate change in the world is a fact and a changing climate can lead to a higher probability of extreme weather to occur (Albihn *et al.*; SMHI 2021a). There have been several occurrences with extreme weather in Sweden and the agriculture sector is one sector that has been affected by this (Albihn *et al.* 2021). Extreme weather is either defined as climatic extremes that occur infrequently or as weathers that severely impact the society and the environment (SMHI 2021a). Examples of extreme weather that have affected the agriculture sector are drought, that has caused a feed shortage, and floods, that have destroyed pasture and crops.

In addition, the Swedish self-sufficiency in regards of animal based food products is already low and vulnerable to these kinds of impacts (LRF 2021; Albihn *et al.* 2021). The number of milk producers has been reduced by half in the last ten years and the total number of dairy cattle has also decreased. Despite this fact, the milk production has increased by 6% per cow and by 79% per supplier/herd. These gains are probably a consequence of a combination of improved overall management, feed, breeding strategies, and in general larger farms (Albihn *et al.* 2021).

There are regulations in Sweden for milk producers stating that they must keep their cattle on pasture for a certain amount of time every day during the grazing season (SFS 2019:66). While the warmer climate could contribute to a longer grazing season, which could be beneficial in an animal welfare perspective (Ketelaar-De Lauwere *et al.* 1999; Wiktorsson & Spörndly 2002; Falk *et al.* 2012), it could also mean a higher exposure to more extreme weather and consequently heat stress (Albihn *et al.* 2021). Dairy cattle are vulnerable to heat stress, especially during both pregnancy and lactation (Bagath *et al.* 2019) and it will influence the health, reproduction, production and welfare of cows (Becker *et al.* 2020).

A central part when talking about health in dairy cattle is of course udder health, as clinical mastitis i.e., inflammation of the udder is the most common disease in dairy cattle. Poor udder health and mastitis can have large economic and welfare consequences for the dairy industry (Seegers *et al.* 2003; Schwarz *et al.* 2020). One challenge with having a dairy farm with an automatic milkings system (AMS) is managing to keep up the cow traffic and milking frequency during the grazing season (Jacobs & Siegford 2012). The variation in time between AMS visits could also possibly impact the udder health negatively (Mollenhorst *et al.* 2011). The Swedish pasture regulations and an AMS in combination with a warmer climate and an already existing vulnerability to heat stress in dairy cattle leads to new challenges for which guidance and preventative measures are needed.

1.1. Aim

This study was a part of the project "Extreme weather – impacts on health and productivity of dairy cows". That project aims to investigate how herd characteristics and climatic factors affect somatic cell count (SCC), productivity and fertility. A part of the project is also to investigate how milk producers react on extreme weather conditions and how prepared they are to take certain measures to act against those conditions. Lastly, the aim of that project is to quantify the costs and benefits of different housing factors and management routines that counteract the possible effects of extreme weather conditions.

The aim of the present study was to investigate the impact of warmer periods on SCC and milking frequency on farms with an automatic milking system (AMS) as well as explore the different pasture characteristics and management strategies used on these farms. In addition, the effect of these strategies in maintaining a low mean proportional difference between winter and summer SCC during warmer periods and grazing season is investigated.

1.2. Research questions

The following research questions are explored in this study:

- Which pasture related characteristics and management strategies do Swedish AMS farms apply during warmer periods to avoid negative effects on udder health?
- Are there any differences in pasture/management strategies applied on farms where SCC increase during summer compared to farms that are less affected?

- Which pasture related characteristics and management strategies in Swedish AMS farms influence the milking frequency during warmer periods?
- Are there any differences in pasture/management strategies applied on farms where milking frequency decrease during summer compared to farms that are less affected?

2. Literature

2.1. Why is udder health important?

2.1.1. Consequences of poor udder health

Economic

Udder health, and mastitis in particular plays a central role in the dairy industry, mostly because it is the costliest and most prevalent disease in dairy herds worldwide. Mastitis is an inflammation of the udder which is commonly caused by a bacterial intramammary infection (Seegers *et al.* 2003; Schwarz *et al.* 2020). The economic consequences of mastitis are caused by several factors including changes in product quality, milk production losses, additional work, diagnostics, treatment, veterinary services, culling and the risk of other diseases (Halasa *et al.* 2011).

Mastitis can either be subclinical or clinical. During subclinical mastitis the udder and milk appear normal although there is an ongoing intramammary inflammation, infection, or both. The clinical form on the other hand is associated with more or less severe symptoms combined with visible and/or palpable changes in the udder and milk, sometimes also an impaired general condition of the cow (Schwarz *et al.* 2020; SVA 2021). Approximately 70-80% of the total financial losses caused by mastitis are caused by the subclinical form (Seegers *et al.* 2003; Halasa *et al.* 2011).

Animal welfare

Besides the economic consequences, mastitis also has adverse effects on the welfare of dairy cows (Schwarz *et al.* 2020). The clinical form of mastitis can be a painful and severe disease (Schukken *et al.* 1993). Reduced lying time has been described as a behavioural response to clinical mastitis. This is contradictory from the usual sickness behaviour observed in cows but can be explained as the cows with clinical mastitis are trying to cope with the discomfort or pain caused by the swollen udder when lying down (Siivonen *et al.* 2011). Furthermore, behavioural changes such as decreased activity and feed intake have also been reported in cows with clinical mastitis (Fogsgaard *et al.* 2012; Medrano-Galarza *et al.* 2012). The subclinical form of mastitis has been observed to impact the so-called luxury behaviour of cattle meaning behaviour such as social interactions and grooming (Caplen & Held 2021). Both clinical and subclinical mastitis are also a common reasons for culling (Växa Sverige 2021).

Antimicrobial usage

Mastitis is the main reason for treating adult dairy cattle with antibiotics (Kuipers *et al.* 2016; Växa Sverige 2020a; Schwarz *et al.* 2020). Krömker & Leimbach (2017) claimed that even though antimicrobial resistance (AMR) currently is not a burning issue in the dairy industry, it is desirable to optimize the usage of antimicrobial substances. One crucial part of this is to prevent udder diseases and improve the udder health of dairy cows, consequently decreasing the incidence of mastitis and number of cows in need of antimicrobial treatment (Oliver & Murinda 2012; Krömker & Leimbach 2017). In Sweden, clinical cases of mastitis are mainly treated with antibiotics, while subclinical cases are recommended to be treated with intramammary antibiotics during the dry period (SVS 2019).

2.1.2. Measuring udder health

A measurement which is commonly used for intramammary infection and milk quality is the somatic cell count (SCC). The measurement can be used at udder quarter, cow, herd, and population level (Schukken *et al.* 2003; Schwarz *et al.* 2020). The somatic cells that are measured in the milk mainly consist of cells that are a part of the immune system of the cow such as polymorphonuclear cells, macrophages, and lymphocytes (Pillai *et al.* 2001). Thus, the somatic cell count reflects the cow's inflammatory response to an intramammary infection or another trigger to its immune system (Schukken *et al.* 2003). Guide values for SCC are that udder quarters with a SCC below 100 000 cells per ml are considered healthy and that quarters with a SCC above 200 000 cell per ml are probably infected (Andersson *et al.* 2011). On herd level, a herd with a bulk milk SCC below 150 000 cells/ml are considered to have good udder health (Juverportalen 2021).

The farmers connected to the Swedish cattle database (SCD) send in milk samples from all lactating cows in their herd approximately once a month to analyse the SCC and a few other markers (milk yield, protein, urea, and fat) on cow level. Thus, it is possible to follow the individual SCC continuously over time (Växa Sverige 2020b). It should also be mentioned that there are other inflammatory markers in milk that can be measured are electrical conductivity and different enzymes (Pyörälä 2003), but these markers are not analysed in the milk samples included in SCD.

2.1.3. Udder health of Swedish dairy cattle

There are currently 2955 dairy farms in Sweden (Grimstedt 2021) and approximately 2147 of them were affiliated to a Swedish cattle farmers association and the SCD in 2020 (Växa Sverige 2021). Mastitis in Swedish dairy cattle reflects what has been observed globally and it is currently the most common and the costliest disease affecting dairy cows in Sweden (Seegers *et al.* 2003; Schwarz *et al.* 2020; SVA 2021; Växa Sverige 2021). The median calculated SCC from the control year 2019/20 based on farms affiliated with the SCD was 237 000 cells/ml. The 10th percentile was 144 000 cells/ml and 90th percentile was 359 000 cells/ml. Whereas the mean for AMS farms was 267 000 cells/ml (Växa Sverige 2020c).

The Swedish mastitis incidence in 2020, based on data from the farms in the SCD was 8.8 diagnosed cases per 100 completed/interrupted lactations (Växa Sverige 2021). The incidence of systemic antimicrobial treatment of dairy cows in Sweden is low and only 12 out of 100 cows per year are treated. Mastitis contribute to the highest proportion of the systemic antimicrobial treatment and correspondent to 61% of the total use (Växa Sverige 2020a).

The most observed microbial diagnosis in Sweden from quarter milk samples from cows diagnosed with either clinical or subclinical mastitis is the bacteria *Staphylococcus aureus* (Persson *et al.* 2011; Duse *et al.* 2021). The second and third most common bacteria from milk samples from cows diagnosed with clinical mastitis are *Streptococcus dysgalactiae* and *Escherichia coli* (Duse *et al.* 2021). For the subclinical mastitis the second and third most common are Coagulase-negative staphylococci (CNS) and *Streptococcus dysgalactiae* (Persson *et al.* 2011). *S. aureus* and *S. dysgalactiae* infect the udder by spreading from one cow to another via direct or indirect contact. Depending on species, CNS can either infect the udder by spreading from one cow to another or from the environment to the udder, while *E. coli* is strictly environmental (Landin 2012).

2.2. Why is udder health impaired during summer?

2.2.1. Heat stress

The definition of heat stress is the sum of internal and external forces acting to increase the body temperature of an animal, this then stimulates a physiological response (Yousef 1985; Dikmen & Hansen 2009). Heat stress in dairy cows has a negative effect on several physiological functions such as overall health, reproduction, milk production and immune function (Tao *et al.* 2018; Rakib *et al.* 2020). A reduction in feed intake is one of the first visible signs of heat stress. Other signs include increased standing time and water intake. All these are efforts to decrease the internal heat load and increase the heat loss (Collier *et al.* 2006).

Thermoneutral zone

Dairy cattle will experience heat stress when exposed to ambient temperatures above their thermoneutral zone (Bagath *et al.* 2019). The thermoneutral zone (TNZ) is a temperature range where the cow doesn´t have to spend energy to uphold a normal body temperature (Becker *et al.* 2020). The TNZ in mature cattle ranges from -15 to 25°C (Dahl 2018) and in lactating cows from 5 to 25°C (Kadzere *et al.* 2002). Some cattle breeds are better adapted to a warmer climate and may have a higher tolerance to warmer temperatures (Riley *et al.* 2012). When the temperature is within the TNZ the cows manage to maintain a normal body temperature ranging between 38,4 and 39,1°C (Das *et al.* 2016). Kadzere *et al.* (2002) mentioned the different responses to temperatures above TNZ studied in cows. These responses include increased rectal temperature and respiration rate, drooling, sweating, panting, decreased feed intake and reduced milk production (Kadzere *et al.* 2002).

Temperature-humidity index

There are different sorts of indices to measure the level of heat stress affecting cattle and other animals. Temperature-humidity index (THI) is the most common of these indices (Dikmen & Hansen 2009). THI integrates environmental temperature and relative humidity but does not take wind speed and solar radiation into account. As a result of this there can be some limitations when it's used for detecting heat stress affecting animals on pasture (Tao *et al.* 2020). A THI at 68 are sometimes used as a lower threshold for heat stress in high lactating dairy cows. This is for example equivalent to a temperature of 25°C and a humidity at 20% (SMHI 2021b).

The summer 2018 stood out among other summers in terms of warm weather in Sweden (SMHI 2021b). THI values up to 80 were measured in several parts of the country. THI values between 80-89 are defined as moderate heat stress with elevated body temperature and respiratory rate and a higher risk of death for cattle. The temperature and THI were also high during a long period of time. In some parts of the country during the summer in 2018 the THI measurements did not drop below 68 for approximately 40 days in a row (SMHI 2021b).

Impact on the immune system

The acute form of heat stress may stimulate the immune system whereas chronic heat stress on the other hand may act as an immune suppressor. Heat stress in dairy cattle will lead to a reduction of antibodies, chemokines, cytokines, and heat shock proteins and thereby lead to a compromised immune status. Exposure to heat stress, as other stressors, causes an increase in circulating cortisol and prolactin (Dahl

2008; Bagath *et al.* 2019). The cortisol will impair the immune functions of the cells by inhibiting gene expression involved in cytokine production and activation of T-cells (Bagath *et al.* 2019). The prolactin will cause a decrease in PRL receptors trough negative feedback and impact the immune function negatively because of the reduced responsiveness in the receptors (Amaral *et al.* 2010; Das *et al.* 2016).

Impact on the udder health

In a review written by Rakib *et al.* (2020), focusing on heat stress and udder health, it was concluded that the number of studies are limited in regards of focusing on the direct effect of heat stress on udder health. The studies available describe an increased SCC and higher prevalence of clinical mastitis during the summer compared to during the winter (Rakib *et al.* 2020). The compromised immune function caused by heat stress exposure during the summer may partly explain the rise in SCC (Tao *et al.* 2018).

2.2.2. The role of pasture

Washburn *et al.* (2002) found that pastured cows consistently had a lower incidence of clinical mastitis than cows in a confined system. It’s been suggested that one contributing factor would be that the exposure to environmental bacteria is lower on pasture and that there is a lower risk of teats being trampled (damaged teats are a risk factor for mastitis). On the contrary there is a higher risk for summer mastitis that is commonly caused by the bacteria *Trueperella pyogenes* which is partly spread by flies (van den Pol-van Dasselaar *et al.* 2008; Arnott *et al.* 2017).

Grazing of cows and pasture vary a lot between different countries due to tradition, climate and herd structure (Wiktorsson & Spörndly 2002). In Sweden, access to pasture is regulated by law. The Swedish animal welfare ordinance states that dairy cattle older than six months shall be kept on pasture during the summer season (SFS 2019:66). Cattle should have access to grazing for at least 6 hours in a row every day. The length definition of the summer season varies from two to four months depending on where in the country the farm is located; the season is shortest in the north part and longest in the south part of Sweden (Jordbruksverket 2021). In addition to this, milk producers that are KRAV-certified (Swedish certification for organic food products) have further grazing requirements to fulfil. These include that the farmers should work toward to have their cows being out on pasture for more than 12 hours per day during the summer season. They should also have a daily grazing intake of at least 6 kg dry matter (KRAV 2021).

2.2.3. The role of milking system

One of the challenges associated with an AMS during periods when the cows have access to pasture is to get them to return to the barn regularly and visit the milking unit. It is therefore critical to understand the mechanisms and incitements that effectively motivates the cows with access to pasture to come back to the AMS the desired number of visits per day (Jacobs & Siegford 2012).

There were 385 farms (connected to SCD) with an AMS in Sweden in 2020. The average SCC for conventional farms has been lower compared to average SCC for AMS farms during several years (Växa Sverige 2017, 2018, 2019, 2021). There has also been a significant difference ($p<0{,}001$) in calculated mean SCC from 2019 and 2020 observed between farms with an AMS (276 000 cells/ml) compared to farms with a conventional system (240 000 cells/ml) (Växa Sverige 2020c). This trend, with higher SCC observations in AMS farms, has also been observed internationally (Klungel *et al.* 2000).

Milking interval and udder health

Milking interval is the time between milkings while as milking frequency is the number of milkings per day. The milking interval an the milking frequency are dependent on each other (DairyNZ 2021). There are a few factors that have been associated with milking interval that may have an influence on udder health. These factors are increased pressure in the udder when the intervals increase and become too long, clearance of pathogens from the udder when milking as well as the total teatcup-on time. A prolonged teatcup-on time increase the risk of teat damage during milking and the risk of invasion of bacteria during and after milking (Mollenhorst *et al.* 2011).

Mollenhorst *et al.* (2011) found a weak association between milking interval and SCC and concluded that the effect of milking interval on SCC was small when adjusted for other variables such as cow and farm characteristics. However, another finding from the same study was that there was a positive association between the variation in milking intervals and SCC. This is an indication that variation in milking interval is more important than the milking interval itself in time when it comes to affecting the SCC (Mollenhorst *et al.* 2011). Similar findings are mentioned in another study where the importance of having a regular milking interval is discussed as possibly the more crucial factor rather than having frequent milkings (Wredle 2005).

Milking frequency and pasture

As previously mentioned, the cows voluntarily visit the milking unit in an AMS which can possibly lead to unwanted prolongation and variation in milking intervals

(Lakic 2011). It is suggested that the voluntary milking frequency will decrease in an AMS when cows get access to pasture, which would consequently lead to prolonged milking intervals. Results from a survey that was carried out in the Netherlands on 25 farms with an AMS in combination with grazing showed that the average number of milkings was 0.2 milkings per cow and day lower in the summer (when grazing) than in the winter (Heutinck *et al.* 2004).

Other studies have found that the milking frequency of grazing cows varied from 1.4 to 2.3 milkings per day with higher frequency for cows that also got feed in the barn compared to those with grazing only (Ketelaar-De Lauwere *et al.* 1999; Jago *et al.* 2004). Ketelaar-De Lauwere *et al.* (1999) also discovered that cows with access to pasture all hours of the day spread their visits to the milking unit less evenly than those with restricted access to pasture.

2.3. Potential strategies for maintaining good udder health during summer

As udder health depends on multiple factors, strategies for maintaining a good udder health during summer includes a range of different factors to consider. Reducing heat stress, keeping a constant milking interval, and retaining cow traffic are a few examples relevant for this study (Lievaart *et al.* 2007; Jacobs & Siegford 2012; Becker *et al.* 2020).

2.3.1. Reducing exposure to solar radiation

A strategy that farmers can use to avoid solar radiation (and thereby heat stress) is letting cows out on pasture at night. This is supported by research suggesting that cows preferred to be indoors during the day and had a preference of being on pasture during the night (Arnott *et al.* 2017). In addition to this Falk *et al.* (2012) found that cows will choose to stay indoors during periods when the daily THI is high when given the choice. It was also observed that the cows mainly chose to access the pasture during the night when the conditions were milder (Falk *et al.* 2012).

During summer, when it´s sunny weather and the temperature is high, dairy cattle will seek shade on pasture (Ketelaar-De Lauwere *et al.* 1999; Wiktorsson & Spörndly 2002; Tucker *et al.* 2008). It has been estimated that when a well-designed shade is provided at pasture the total heat load would be reduced from 30 to 50% (Collier *et al.* 2006). In addition, studies show that cows provided with shade during summer conditions have lower body temperatures (Collier *et al.* 2006; Tucker *et al.* 2008), respiratory rate (Collier *et al.* 2006; Schütz *et al.* 2010), show less signs of panting and spend less time at the water troughs (Schütz *et al.* 2010) compared to those without shade. Shade is also considered an important factor to minimize a decrease in milk production and reproductive efficacy. For example Van Laer *et al.* (2015) found that cows with access to shade didn’t have the decrease in milk yield that was observed in cows without shade and Collier *et al.* (2006) found that cows provided with shade yielded 10% more milk than those without.

It has been observed that use of shade also occurred on days with levels of low solar radiation, however the use of shade has been observed to peak when the levels of solar radiation are the highest indicating the importance of providing enough shade for all cows on pasture (Tucker *et al.* 2008; Schütz *et al.* 2014). An estimation made by Collier *et al.* (2006) was that a mature dairy cow require a shaded space of 3.5 to 4.5 m^2. If the shaded space per cow is inadequate it may result in udder injuries as the cows probably will crowd together (Collier *et al.* 2006).

Although shade will reduce the accumulation of heat from solar radiation it will have no effect on the air temperature or relative humidity. Therefore additional cooling such as sprinklers or misters often need to be used for lactating cows in humid hot climate to reduce heat stress further (Collier *et al.* 2006).

2.3.2. Using water to support cow traffic

Limiting the water access to only the barn for cows with access to pasture is sometimes used as an incitement to get the cows to come into the barn and use the milking unit (Ketelaar-De Lauwere *et al.* 1999). Spörndly & Wredle (2005) concluded that this may not be an effective method as there seemed to be no difference in milk production or milking frequency between cows that have water only in the barn compared to those that have water available in the barn and on pasture. This was investigated with walking distances up to approximately 300 m in a farm with an AMS. Behaviour observations showed that cows with water on pasture spent more time outside and more time grazing than the cows that had to go inside to drink. The cows with water both on pasture and inside the barn also drank more than 50% of their total water consumption outside, which was an indication that they were thirsty and wanted to drink while being on pasture (Spörndly & Wredle 2005).

Ketelaar-De Lauwere *et al.* (1999) found that cows with access to grazing (and no water on pasture) spent less time at the drinking troughs compared to those that didn´t have access to grazing. Which could imply a lower water intake (Ketelaar-De Lauwere *et al.* 1999). In addition to this it has been discussed that a decrease in water intake could lead to a lower milk yield (CORDIS 2005).

It is recommended having water on pasture because of animal welfare reasons and since no advantages are associated with limiting the water supply to only inside the barn (Spörndly & Wredle 2005). In addition to this Blackshaw & Blackshaw (1994) stated that cattle will only be able to tolerate summer weather conditions if they have free availability to water. Water availability is especially important during summer with high ambient temperature when there is a risk for the cows to experience heat stress (Mader *et al.* 1997).

3. Material and method

3.1. Study design and study population

Farms were selected for interviews based on data from the SCD. Farms participating in the SCD with more than 50 cows were investigated considering data on fertility and somatic cell counts from 2016-2019.

Farms across Sweden were recruited to the project by local veterinarians and advisors through Växa Sverige. Before the study was started, power calculations were used to estimate that 30 cases and 30 controls were required to identify risk factors with odds ratio of 4. To ensure recruitment of a varied study population (farms that were impacted by summer and farms that were not impacted by summer), a list of 240 farms was created based on seasonal change (proportional deviation from average SCC during summer compared with average SCC during winter) according to udder health statistics from 2016-2019. Of the 240 farms, half (120 farms) were the farms that had the smallest deviation from yearly SCC average and half were farms that had the largest deviations. Another list of 240 farms was created based on the fertility measurement FVT30, a measurement that presents the proportion of pregnant cows in a herd 30 days after the, by the farmer, voluntary waiting time (FVT for short in Swedish). As for SCC, half (120 farms) had a small or no deviation in FVT30 during summer compared to in winter and 120 had the largest deviation from their average FVT30 during the same period. When the two lists were combined, some farms were included in both lists and in the end the investigation resulted in a list including 421 farms in total. The participating veterinarians and advisors were instructed to recruit from all 4 groups (small or large deviation in SCC and FVT30 respectively) for either a physical visit or for a phone interview. In total 54 farms were recruited for a phone interview in spring 2021 and in this study the 26 farms that had an AMS were included.

3.2. The interviews

After recruitment, the farmers were contacted via text message to schedule a time for the interview. Farmers were interviewed two times, in spring and fall. Of the 54 farms interviewed in spring 9 declined participation in the follow-up interview. The first set of interviews were completed in February, March, and April 2021 by three advisors at Växa Sverige and a master student in animal science. The second set of interviews were carried out by telephone during September the same year. Both interviews took approximately 40 minutes to finish. Of the interviews performed in September, the author interviewed 23 farmers and 22 farmers were interviewed by another veterinary student also writing her master thesis. The questionnaire included questions about the farmers experiences of the summer months of 2021 concerning pasture, water, ventilation, feeding, milking routines, udder health and fertility (Appendix 1). The questionnaire was piloted with advisors with experience from working on dairy farms before the start of the survey.

3.3. Mean proportional difference

Information about the SCC from the 26 selected AMS farms monthly milk recordings during the years 2017 to 2019 were collected from SCD. The SCC data from 2016 was excluded because it was deemed to be too old and therefore irrelevant to include.

The mean herd calculated SCC (MHSCC) for the periods January to April (winter) ($WMSCC_{20xx}$) and June to September (summer) ($SMSCC_{20xx}$) respectively were calculated separately for each year. Based on these averages the difference between the winter period and the following summer for every year could be calculated ($DMSCC_{20xx}$) and then the proportional difference (PD_{20xx}). Finally, the overall mean proportional difference (MPD) from the proportional differences of three years were calculated.

$$\frac{MHSCC_{jan20xx} + MHSCC_{feb20xx} + MHSCC_{march20xx} + MHSCC_{april20xx}}{4} = WMSCC_{20xx}$$

$$\frac{MHSCC_{june20xx} + MHSCC_{july20xx} + MHSCC_{aug20xx} + MHSCC_{sept20xx}}{4} = SMSCC_{20xx}$$

$$SMSCC_{20xx} - WMSCC_{20xx} = DMSCC_{20xx}$$

$$\frac{DMSCC_{20xx}}{WMSCC_{20xx}} = PD_{20xx}$$

$$\frac{PD_{2017} + PD_{2018} + PD_{2019}}{3} = MPD$$

3.4. Categorization of open questions

The questionnaire included several open questions where the interviewees could answer in their own words. These questions included in what way they thought the mastitis pattern changed in the summer and how frequently they cleaned their water throughs and drinking cups. It also included the questions: "what strategy do you have to prevent a prolonged milking interval?" and "what pasture strategies do you have to maintain the milk production during the summer?" (Appendix 1). The answers to these questions were categorized by similarity to make them comparable. The answers that only occurred once were categorized in an "other"-category.

The distances to pasture from the barn was divided into two groups, since it also was an open question, those with: 0-260 m and >260 m to pasture. The furthest distance to pasture was included if there were pastures with different distances mentioned in the answers. This cut-off was chosen because it was used in a Swedish study where cows that had distance of 260 m between barn and pasture were observed to have fewer visits to the barn compared to the cows with pasture right outside the barn (Wredle 2005).

3.5. Descriptive and statistical analysis

Data was entered into Excel which was also used to create descriptive figures for exploratory analysis. Mainly boxplots were made to study the different parameters and visualize the differences in average deviation from the proportional SCC and milking frequency for different categories of the explanatory variables. The boxplot shows the interquartile range (IQR; the distance between the third and the first quartile) median, maximum, and minimum values, and outliers (values 1,5 times the IQR larger than third quartile or 1,5 times the IQR smaller than the first quartile) for each parameter.

Two types of statistical test were then used to make comparisons between the different answer categories and to investigate the different factors associated with

SCC and milking frequency. The data (mean proportional difference 2017-2019, milking frequency and mean summer SCC 2017-2019) was investigated using histograms to see if it was normally distributed. Since the data was not normally distributed a Mann-Whitney test and Kruskal-Wallis test was used. The association between mean proportional difference 2017-2009 and overall monthly SCC for 2017-2019 was analysed using Mann-Whitney test. The Mann-Whitney test was done using an online calculator (Vassarstats 2021a) and used to test questions with two levels, for example questions with only "yes"- and "no"-answers. A Kruskal-Wallis test was also done using an online calculator (Vassarstats 2021b) and then used to compare questions with more levels than two. The different variables that were compared are included in Table 1.

Table 1. Variables and the responses investigated in the study. Open questions were categorised according to responses in the table as part of the analysis.

Questions/Topics	Responses			Open question
Milking frequency (MF) during summer compared to winter	Higher MF	Lower MF	No difference	Yes
Do you experience less milkings in the summer?	Yes	No		No
Do you prevent a prolonged milking interval in the summer?	Yes	No		No
Do you have a strategy to entice he cows to go inside?	Yes	No		No
Water on pasture (water throughs or drinking bowls)	Yes	No		No
Cleaning water troughs (in the barn)	Everyday	Less frequently		Yes
Cleaning water troughs (on pasture)	Everyday	Less frequently		Yes
Shade on pasture	Good access	Limited access	No access	No
Percent feed intake trough grazing (in July)	0-30	31-60	61-90	Yes
Access to pasture	Limited	Unlimited		Yes
Distance to pasture	0-260 m	>260 m		Yes

3.6. Farms with high SCC

As mentioned in the paragraph about study population, the data with the 26 farms with both a low and high deviation from their mean SCC were included, in disregard what their mean herd SCC were. To investigate if the associations seen from the Mann-Whitney tests and Kruskal-Wallis tests was affected by herds with a high SCC and a small seasonal deviation from their mean SCC, the analyses were re-run without those herds.

4. Results

4.1. Farm data

Out of the 45 farms that were interviewed twice there was a total of 26 farms with an AMS. The 26 farms were distributed among 15 different counties in Sweden (Figure 1). The average herd size among these farms were 102 milking dairy cows and the median was 102.5 milking dairy cows. Half of the farms (n=13) had between 50 and 99 milking dairy cows, ten farms had 100-150 and the remaining three had above 150 (Figure 2). The number of robots per farm ranged from one to three robots depending on farm size.

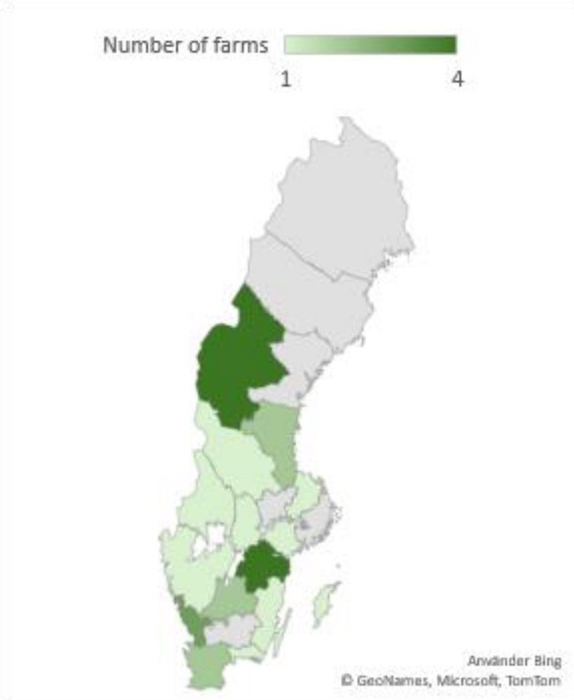


Figure 1. Map of Sweden showing the number of participating AMS farms per county. Map allowed to use as stated: https://www.geonames.org/about.html

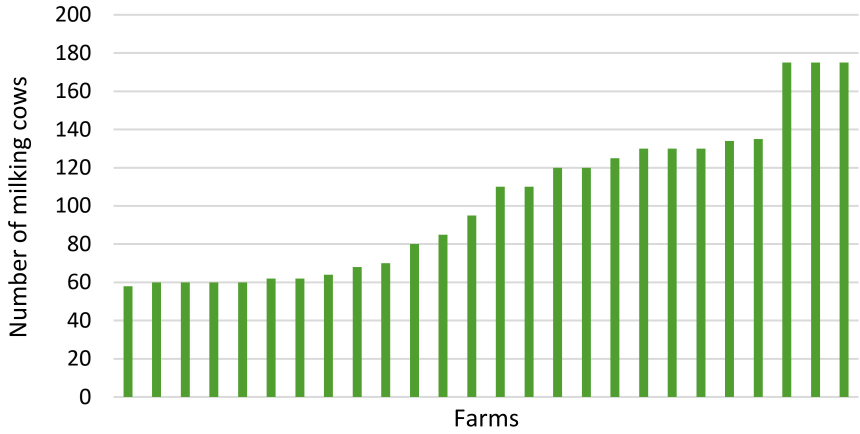


Figure 2. Distribution of the number of milking cows for each farm participating in the study (n=26).

The participating farms either had the DeLaval or Lely AMS-system, 14 farms had DeLaval and 12 had Lely.

4.1.1. SCC and udder health

The proportional differences in SCC from each year was used to calculate the mean proportional difference in SCC 2017-2019 (Figure 3).

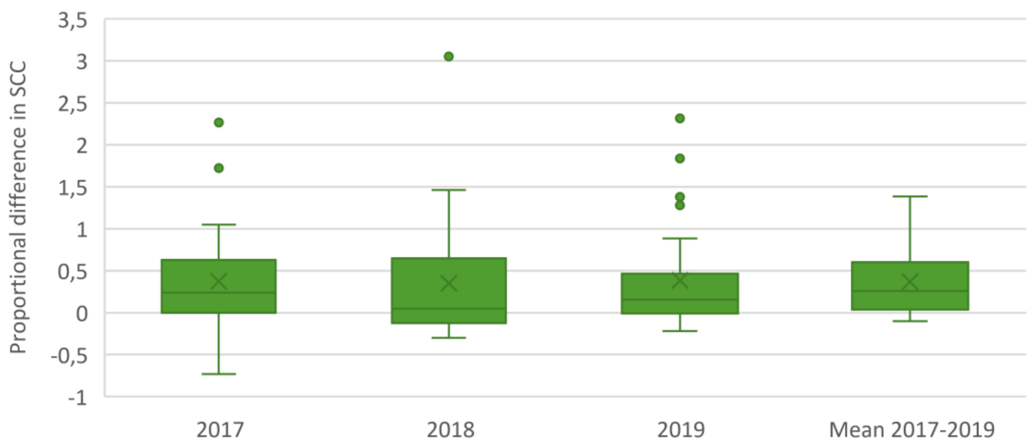


Figure 3. Boxplot of the distribution of the proportional difference between mean winter and summer SCC in 26 dairy farms during the years 2017 to 2019 respectively and summarized as a calculated mean.

An association ($p<0.001$) between mean proportional difference and overall mean monthly SCC based on the monthly SCC 2017-2019 for was found, indicating that farms with a higher overall SCC during the included years had a smaller deviation from their SCC in the summer (Figure 4). When the mean proportional difference was plotted with mean of yearly SCC 2017-2019 visual inspection indicated that the association was driven by four farms with high mean SCC and low mean proportional difference (Figure 4). Statistical tests for the different investigation parameters were run with and without these farms to ensure that these outliers did not impact results and the results remained similar. Therefore, the data from all the 26 farms are presented in the following results.

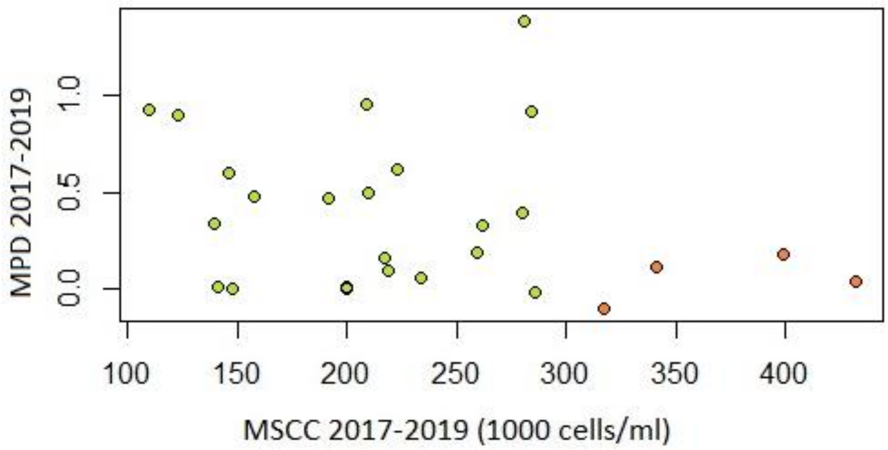


Figure 4. Plot of the mean proportional difference in SCC (MPD) from 2017-2019 in relation to mean SCC (MSCC 2017-2019) during the period 2017-2019 (all months)). The orange dots represent the four farms that were excluded to investigate if farms with a high SCC and small deviation from their mean SCC would impact the p-value of the different tests. The green dots represent the farms that were included in the tests.

In the winter (January to April) 2017 the lowest SCC among the 26 participating AMS-farms was approximately 66 800 cells/ml and the highest 390 200 cells/ml. The summer (June to September) that same year the SCC ranged between 90 200 and 459 500 cells/ml. The following year the SCC ranged between 73 300 and 402 800 cells/ml in the winter and between 93 900 and 529 200 cells/ml in the summer. In 2019 the SCC ranged from 90 300 to 503 000 cells/ml in the winter and from 106 600 to 597 400 cells/ml in the summer (Appendix 2). The mean and median for winter and summer for the three years were also calculated (Table 2).

Table 2. Mean, standard deviation (SD) and median of the summer and winter SCC of the participating 26 dairy farms during the three years that were included in the study. The p25-p75 interval represents the interval from the first to the third quartile (25th and 75th percentile). The unit for SCC is 1000 cells/ml.

	Mean	**SD**	**Median (p25-p75)**
Winter 2017	204	±79	202 (145–249)
Summer 2017	250	±88	247 (206–288)
Winter 2018	208	±94	186 (131–262)
Summer 2018	249	±108	214 (182–314)
Winter 2019	222	±107	203 (139–271)
Summer 2019	281	±128	269 (193–348)

The mean SCC based on data from the three years combined differed significantly between summer and winter (p=0.03), with a higher SCC during the summer for all years (Figure 5).

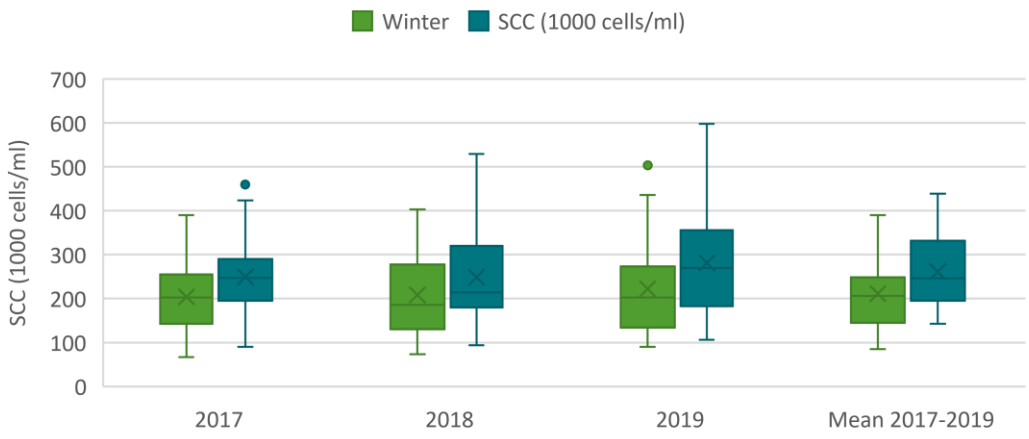


Figure 5. Boxplots of the distribution of SCC during winter and summer in 26 dairy farms in the years 2017 to 2019 respectively and summarised as a calculated mean.

The farmers were asked whether they experienced a different pattern of mastitis (both subclinical and clinical cases) in the summer compared to winter. Half of the farmers (n=13) answered that they did experience a seasonal pattern and the other half (n=13) answered that they didn´t experience this. The farmers that answered yes were also asked to answer in their own words in what way they thought the mastitis pattern changed, and these answers are presented in Figure 7.

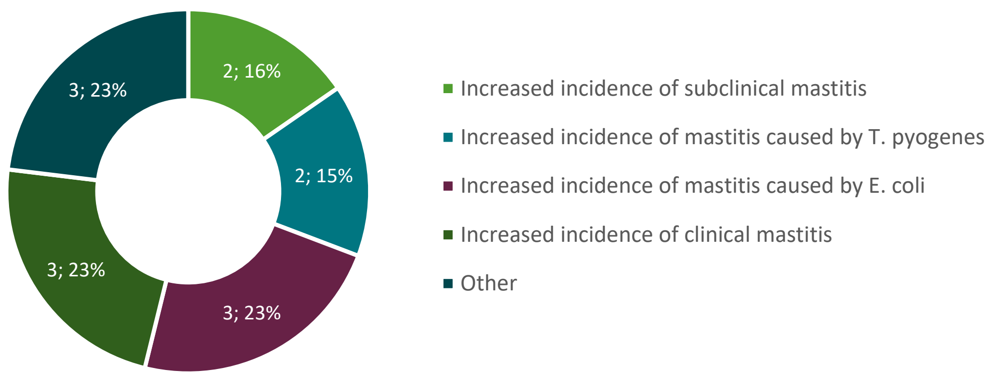


Figure 7. Circle diagram of the distribution of answers for the question "In what way do you experience a different pattern in mastitis in the summer compared to winter?". The "other" category included three answers: An increased vulnerability to mastitis in high producing cows, the mastitis cases are harder to treat in the summer and that the course of the disease is faster, and harder to discover.

4.1.2. Milking frequency

Information about the milking frequency was collected in both the winter and the summer interview. In the winter the frequency ranged between 2.8 and 3.5 and the mean was 2.86 (SD=±0.29). The milking frequency ranged between 2.4 and 3.5 in the summer and the mean was 2.73 (SD=±0.25). The mean difference between winter and summer milking frequencies was 0.13 milkings lower in the summer (Figure 9). There was a significant difference (p=0.04) between number of milkings during winter and summer with a lower milking frequency in the summer (Figure 8).

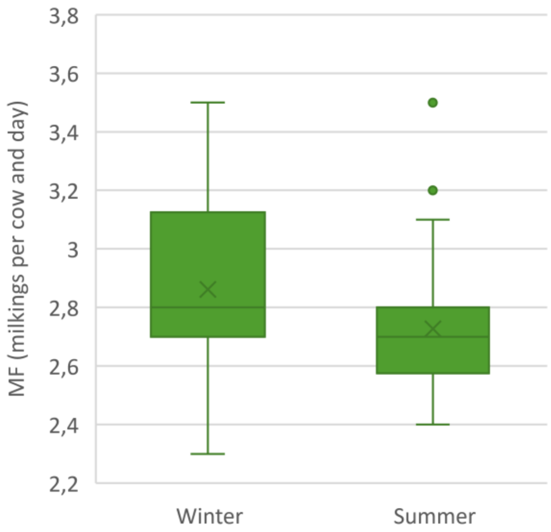


Figure 8. Boxplot of the distribution of the miking frequency on 26 dairy farms during the winter and summer 2021.

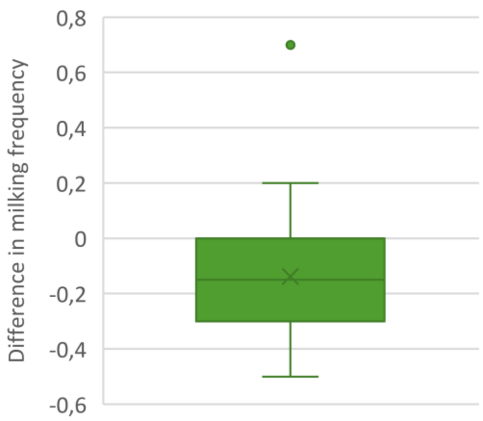


Figure 9. Boxplot of the difference in milking frequency between winter and summer milkings in 2021 in 26 dairy farms.

When compared, 65.4% (n=17) of the farms had a lower milking frequency in the summer than in the winter, 19.2% (n=5) had the same milking frequency and the remaining 15.4% (n=4) had a higher milking frequency during summer compared to winter. When divided into three groups based on difference in milking frequency (higher frequency in the summer, lower frequency in the summer and no difference between summer and winter) and compared to the mean proportional difference in SCC there was no significant difference (p=0.76).

The interview included questions concerning experience with fewer milkings during the summer if they had a strategy to prevent a prolonged interval or to entice the cattle on pasture to return to the barn (Table 3). No significant differences were seen in the distribution of the answers in regards of summer milking frequency and difference in winter and summer frequency. If they had a strategy, they were asked to give examples on how (Table 4). Only 18 of the 26 farmers had some strategy for this and the two most common strategies were fetching the cows from pasture (9 out of 18) or only having water inside (6 of 18).

Table 3. Distribution, and proportion (%) within question, of farmers answers to three questions related to milking frequency and results from the statistical assessment (using Mann-Whitney test) if there was an association between the actual milking frequency in summer (FS) and the difference in summer and winter milking frequency (FD).

	Yes	**No**	**P-value FS**	**P-value FD**
Do you experience less milkings in the summer?	11 (42)	15 (58)	0.39	0.24
Do you prevent a prolonged milking interval in the summer?	12 (46)	14 (54)	0.45	0.14
Do you have a strategy to entice the cows to go inside?	14 (54)	12 (46)	0.54	0.44

Table 4. Distribution of answers to the questions "How do you prevent a prolonged milking interval in the summer" and "What is your strategy to entice the cows to go inside?" combined, as well as mean summer somatic cell counts (SCC) during 2017-2019 and mean milking frequency (MF) in 2021 in 18 dairy farms with an automatic milking system.

Farm	**Fetching cows**	**Water inside only**	**Controlled cow traffic**	**Concentrates in the MU**	**Other ***
1	x	x	x		
2	x		x		
3	x				x
4	x				x
5	x				
6	x				
7	x				
8	x				
9	x				
10		x	x		
11		x		x	
12		x			x
13		x			
14		x			
15			x		
16				x	x
17				x	
18					x

**The other category includes the answers: limited grazing on pasture, free cow traffic during the day, new roughage feed indoors every other hour, avoiding overcrowding, more and offer feeding when cows have been fetched.*

4.2. Pasture characteristics

4.2.1. Water

Half (n=13) of the interviewed farms included in this study provided water on pasture and the other half (n=13) did not provide water on pasture. Approximately half (46%, n=6) of the farmers that did not have water on pasture mentioned it as a strategy and incitement for the cows to return to the barn (Table 3). The mean proportional difference in SCC from 2017-2019 did not statistically differ between the farms that provide water on pasture and those who did not (p=0.92). The groups were also compared regarding mean summer SCC from 2017-2019 (p=0.47), difference in milking frequency (p=0.61) and summer milking frequency (p=0.90) but no differences were observed.

The farmers were also asked to rate their water supply in the barn and on pasture on a scale from 1 to 5 where 1 was that they didn´t think their water supply was enough, 3 that the supply varied and 5 that it was enough. All farmers with only water inside except one (n=12) answered that their supply was enough (5 out of 5), the last one answered a 2 out of 5. Of the farmers with water both inside and outside 54% (n=7) answered that they had enough water supply in the barn and on pasture (5 out of 5) while the remaining 46% (n=6) answered that it varied. Four farmers answered that they had enough water supply in the barn (5 out of 5) and a 3 or a 4 out of 5 on pasture and the other two answered that they had enough water on pasture (5 out of 5) and a 3 or a 4 out of 5 in the barn.

The farmers were also asked how frequently they cleaned their water throughs and drinking bowls in the barn and on pasture. There were 65% (n=17) who answered that they cleaned water throughs and drinking bowls in the barn every day and the remaining 35% (n=9) cleaned them less frequently. Out of those with water on pasture there were 31% (n=4) who cleaned throughs and drinking bowls on pasture every day and the remaining 69% (n=9) cleaned them less frequently (Figure 11). No statistical difference between these groups in regard to mean proportional difference in SCC from 2017-2019 or mean summer SCC from 2017-2019 (p>0.05), were found.

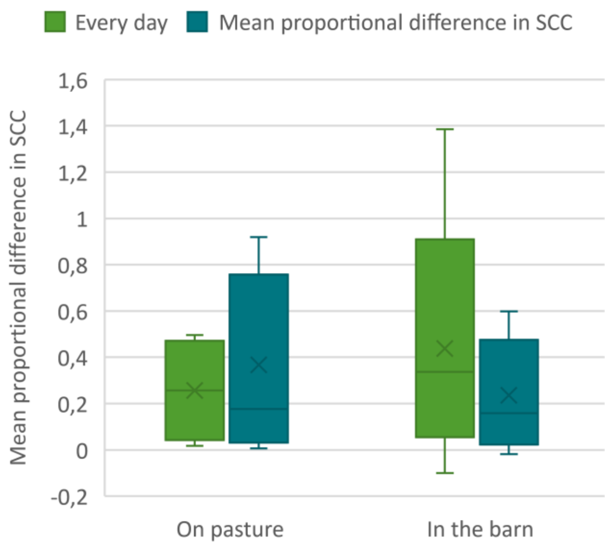


Figure 11. Boxplot of the mean proportional difference in SCC (MPD) in the years 2017-2019 over how often the water troughs and drinking bowls were cleaned in the barn (n=26) or on pasture (n=13) during summer 2021.

4.2.2. Shade

The farmers were asked if their pastures had shade. The majority (54%, n=14) answered that their pastures had good access to shade, 31% (n=8) had answered that there was limited shaded parts on pasture and 15% (n=4) had answered that they didn´t have any shade on pasture. When the mean proportional difference in SCC, mean summer SCC and milking frequency were compared between farms with shade, limited shade, or none, no significance was found (p>0.05) (Figure 12).

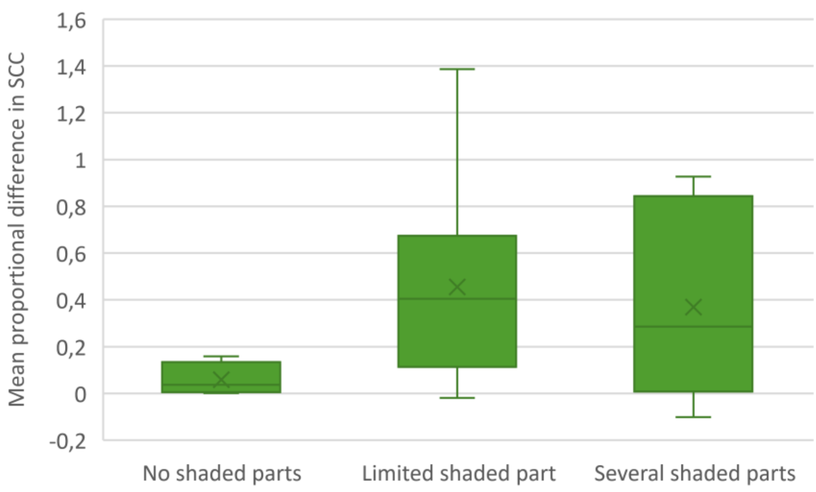


Figure 12. Boxplot of the distribution of mean proportional difference in SCC (MPD) in relation to estimated access to shade on pasture in 26 dairy farms.

4.2.3. Management strategies

The farmers were asked if they had any pasture strategies to maintain milk production during the summer and if they had any, which kind of strategy it was. Almost a third (30%, n=8) answered that they didn´t have a strategy. Out of those who had a strategy, rotating between different pastures was the most common (10 out of 18) (Table 5).

Table 5. Distribution of answers from farmers on what strategies they have to maintain the milk production during summer.

Farm	**Rotational grazing**	**Pasture trimming**	**Release cows on pasture early in the season**	**Other***
1	x	x		
2	x	x		
3	x	x		
4	x			
5	x			
6	x			x
7	x			
8	x			
9	x			
10	x	x	x	
11		x		x
12		x		
13			x	x
14			x	
15			x	
16				x
17				x
18				x

** The other category included three that had exercise pasture and one of each that answered: release cows on pasture late in the season, unlimited access to roughage feed in the barn, let the dry cows graze before the milking cows, and no water on pasture.*

There was a question where the farmers were to estimate how many percent feed intake through grazing the cattle had eaten in July 2021. The majority estimated a feed intake of 0-30% (65.4%, n=17), 19.2% (n=5) estimated a feed intake of 31-60% interval and 15.4% (n=4) a feed intake of 61-90% interval. The milking frequency in the different groups were compared but no statistical significance was found (p=0.87). However, when mean proportional difference in SCC were compared between the three groups (Figure 13) a significant difference was found (p=0.01).

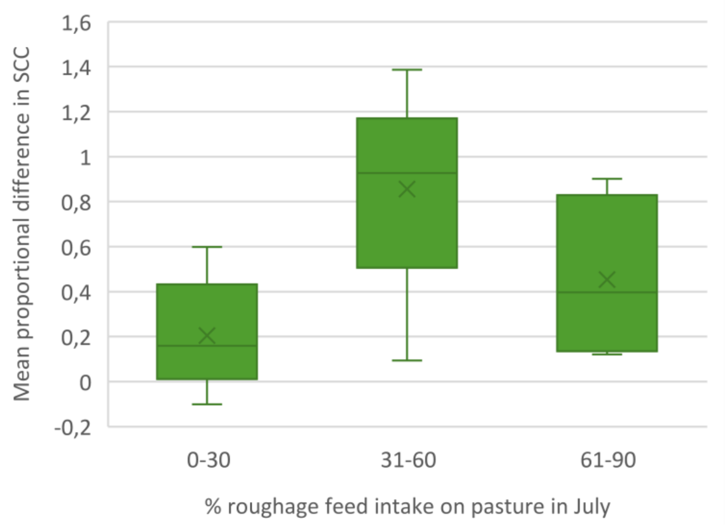


Figure 13. Boxplot of the distribution of mean proportional difference in SCC (MPD) in relation to the estimated proportion of roughage feed intake on pasture in July 2021 in 26 dairy farms.

4.2.4. Access to pasture

The interview included a few questions related to when the cows had access to pasture. The majority (77%, n=20) answered that their milking cows had free access to pasture and the barn 24 hours (or very close to 24 hours) a day. Those who had limited access to pasture consisted of those who had access only during the night (8%, n=2), only during the day (11%, n=3) or during the day or the night (4%, n=1). The cattle in the groups with limited access had an access ranging between 6.5 and 16 hours per day. The two groups (unlimited and limited access) were compared regarding summer milking frequency (p=0.27) (Figure 14), but no significant differences were found. However, when compared regarding difference in milking frequency between summer and winter (p=0.01) (Figure 15) the groups differed significantly. The mean proportional difference in SCC (p=0.98) was also compared in the two groups and there was no significant difference.

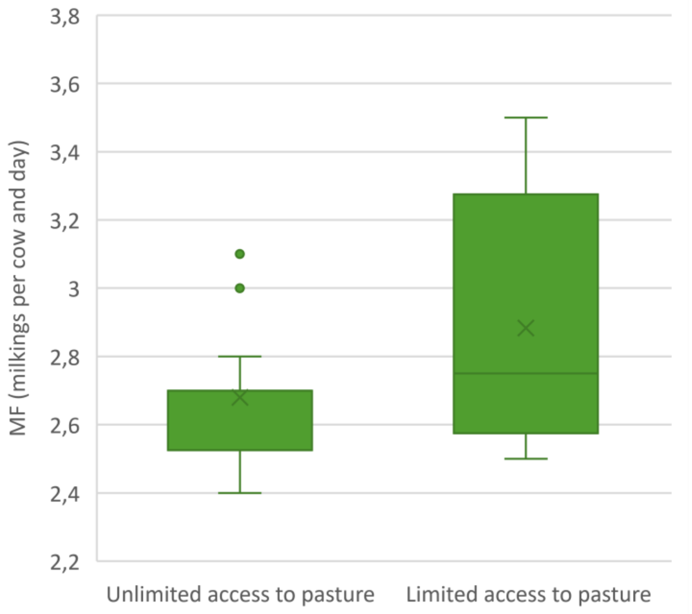


Figure 14. Boxplot of the distribution of summer milking frequency in relation to unlimited or limited access to pasture in 26 dairy farms.

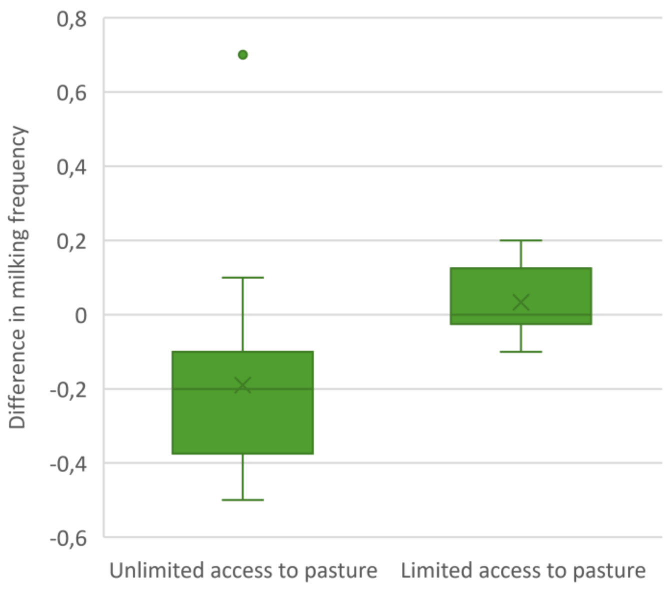


Figure 15. Boxplot of the distribution of difference in milking frequency between winter and summer in relation to unlimited or limited access to pasture in 26 dairy farms.

4.2.5. Distance to pasture

The farmers were asked to about their distances from the barn to the pasture. The question was added after a few interviews already was done so 19% (n=5) of the answers was not included, 54% (n=14) had 0-260 m to pasture and 27% (n=7) had >260 m. The two distance groups were compared regarding summer milking frequency (p= 0.17) (Figure 16) and difference between winter and summer milking frequency (p= 0.83) both of which were not statistically significant. No significance was found when mean summer SCC (p=0.17) or mean proportional difference in SCC (p=0.85) was compared.

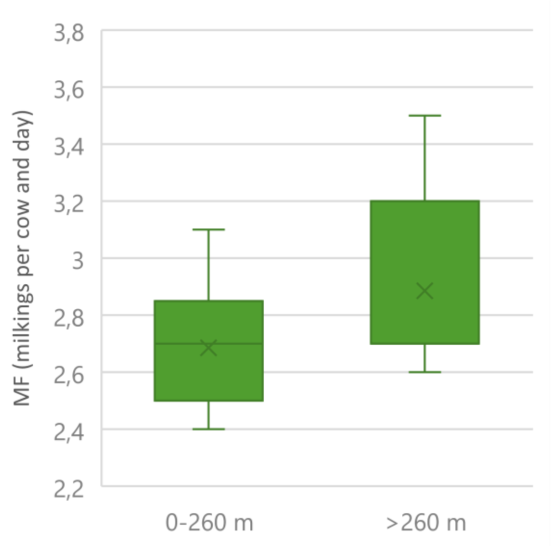


Figure 16. Boxplot of the distribution in summer milking frequency in 2021 between 21 farms with below or above 260m to pasture

5. Discussion

5.1. AMS farms in Sweden and udder health

The AMS farms in Sweden generally have a higher SCC compared to conventional milking parlours (Växa Sverige 2021). In this study there was a difference between the average winter and summer SCC, with a higher SCC in the summer. This pattern is in accordance with what has been shown discussed several international studies which also included conventional farms (Schukken *et al.* 1993; Green *et al.* 2006; Olde Riekerink *et al.* 2007). The extraordinary conditions of the summer in 2018 and its consequences is likely to have impacted the SCC during that current period and both winter and summer the following year since an increase in both range and mean SCC can be observed.

There was a significant seasonal difference in milking frequency, with a lower interval in the summer. This confirms the suggestion that the milking interval decreases when the cows are turned out to pasture. The difference in mean milking frequency between winter and summer (2.86 vs. 2.73 milkings/cow and day, i.e., a difference of 0.13) in the present study was lower compared to the difference of 0.2 milkings/cow and day that Heutinck *et al.* (2004) found. The range of milking frequency during summer was higher (2.4-3.5) than what has been found in other studies (1.4-2.3) (Ketelaar-De Lauwere *et al.* 1999; Jago *et al.* 2004).

5.2. Pasture strategies and characteristics

One strategy that half of the participating farmers used in the summer to ensure that the cows returned to the barn, and then also hopefully went to the miking unit, was to limit the water access and have it only in the barn. However, according to the findings in this study the strategy did not affect the milking frequency. Using water as an incitement for the cows to return to the barn, at least as a purpose to use the milking unit, seems to be an unnecessary strategy based on these results and may negatively impact animal welfare. These results are consistent with what is concluded in another study (Spörndly & Wredle 2005), that using water as incentive did not increase the milking frequency.

No association was found between milking frequency and having distances to pasture below or above 260 m. This result and the parameter may not be very reliable as it is hard to compare distances given in a telephone interview. Some farmers also had different pastures within different distances from the barn which makes the result even more complicated and unreliable. Studies have shown varied results regarding distance to pasture and milking frequency. In one study it was observed that cows with pasture just 50 m from the barn had a higher milking frequency during the initial half of the grazing season compared to cows grazing at a distance of 260 m (Spörndly & Wredle 2004). In contrast, another study found distances up to 360 did not affect the number of visits to the milking unit (Ketelaar-De Lauwere *et al.* 2000).

The results showed a significant difference between limited and unlimited access to pasture on both summer milking frequency and difference in winter and summer milking frequency. The cattle with limited access to pasture had a higher milking frequency and a lower difference in milking frequency between winter and summer. This could probably be because the ones with limited access to pasture visits the milking unit more frequently during the parts of the day that they do not have access to pasture. In a review written by Lyons *et al.* (2014) an analysis of several studies showed that when the time the cattle was offered access to pasture increased, the milking frequency decreased (Lyons *et al.* 2014).

There were four farms that had a higher milking frequency during the summer compared to winter. One thing they had in common was that they estimated that roughage feed intake of the milking cows on pasture during July was ≤30%. However, there was no association found between percent roughage feed intake on pasture and summer milking frequency or difference in milking frequency. So, it could rather be a coincidence than a reason for the higher milking frequency. But a possible explanation for this might be that these cattle may spend less time on pasture and return more frequently to the barn to eat (thus also visiting the milking unit) since the purpose of their pasture is more of a recreational kind rather than for grazing.

Ketelaar-De Lauwere *et al.* (2000) reported that there was an increased cow traffic from pasture to the barn when the pasture had lower heights and biomass. This resulted in a higher milking frequency. If it is assumed that pastures that are supposed to provide cattle with a low roughage feed intake (0-30%) have lower heights and biomass, which is likely, this may be a plausible part of the explanation why these farms manage to increase their milking frequency during the summer. In addition to this, another study mentioned the time spent eating as the one of the main reasons explaining the differences in milking frequency between AMS combined with pasture compared to indoor-based AMS. The results from this study showed that grazing cows spent nearly double the time eating than cows that were based indoor only (Bargo *et al.* 2002).

There was a significant difference between percent feed intake trough grazing in July regarding mean proportional difference, where the 0-30% and 61-90% groups had a lower mean proportional difference compared to the 31-60% group. A plausible reason for this may be that the groups with a low or high feed intake trough grazing may have a more defined strategy for feeding and more able to maintain the udder health during the summer. For example, providing most of the roughage feed inside barn and get the cows to graze only a small part on pasture (0-30%) or grazing most of the roughage feed on pasture and providing a smaller part in the barn (61-90%). Whereas the middle group (31-60%) may not have the same type of strategy and may need to walk back and forth between the pasture and barn more.

There was no significant difference between shade provided and mean proportional difference, but there was still a notable difference between the different groups. In contrary to what may be expected the cows without shade on pasture had a lower mean proportional difference compared to those with shade. This could possibly be explained by that those who are aware of their lack of shade on pasture may let the cows graze during the night instead, or, if they have a well-ventilated and cool barn, the cows may prefer to stay inside during warm and sunny days. Thus, the cows with no shade provided may not have had a higher exposure to solar radiation and heat stress compared to the ones that have shade on pasture.

Both the shade and the percent feed intake on pasture groups would be interesting to compare in regards of other characteristics and strategies such as type of barn and ventilation system. This is because the significant differences in mean summer SCC and mean proportional difference in SCC in the shade and percent feed intake groups could possibly be correlated with differences that may impact the SCC, for example how capable the farms are to maintain a cool barn during warm summer days.

Milking frequency was included as a variable in this study, but other studies seem to be in agreement that managing the variation in milking interval in AMS farms is more important rather than just trying to increase the milking frequency (Ouweltjes 1998; Laurs *et al.* 2010). The variation in milking interval has been observed to have a negative impact on both milk yield (Bach & Busto 2005) and SCC (Mollenhorst *et al.* 2011). In this study, the variation in milking interval was not included but it could possibly be a topic for further research. Particularly to take a closer look at what kind of impact the grazing season has on the variation.

5.3. Limitations and risk of bias

It should be mentioned that when calculating the mean proportional difference in the study, no considerations were taken concerning whether the included AMS farms had good or poor udder health to begin with. The mean proportional difference should therefore only be considered a measurement of a risk of having a great or small deviation between winter and summer SCC and not as a measurement of good or poor udder health.

When performing studies that include interviews, there is a risk of a social desirability bias. Meaning that the interviewee may answer the questions in a manner that is viewed as favourably by others. One example can be the questions about how often the farmers clean their water throughs and drinking bowls. They may feel that they do this too infrequently and instead answer that they do it more frequently than they actually do. This can lead to a higher frequency of reporting desirable behaviour or a lower frequency of reporting undesirable behaviour. There is also a risk with interviews that questions might be interpreted differently depending on both the interviewee and the interviewer. For the summer interview, when there were two interviewers, the questions were gone through together beforehand to see that they were interpreted in the same way to at least avoid one side of this.

Since mastitis have such a multifactorial aetiology, it can be hard to isolate one single factor that will have an impact. There is a risk of confounding bias because of this. Meaning that there is a confounder that will incorrectly imply a causal relation but, there is really a false factor that affects both the independent and dependent variables. Additionally, there is always a risk to interpret significant results from univariate analyses, as was done in this study, as these could be misleading and other factors that are not included in the analysis could be the real reason behind the correlation. To avoid this, multivariate analyses could have been used instead.

Additionally, the farmers that discontinued their participation in the study could also be a possible contribution to the bias of the study. They could for example represent a group that are less motivated to participate because they rarely experience any problems during the summer. It is also plausible that they could have a higher workload during the summer and don´t have time to participate.

It would have been desirable to have a larger sample of farms to answer the questionnaire. Since the focus was chosen to be on AMS farms the conventional farms were excluded which resulted in a smaller sample. When comparing several different categories against each other, the sample size in each group sometimes became very small and this will lead to lower power. Low power will reduce the chance to detect a true effect. Also, when there is a small sample, it is harder to discover smaller differences between the farms. It should also be mentioned that using mean calculations in several steps could erase peak SCCs and give false low values.

Another important aspect to consider is if the selection of AMS farms in the study is representative for AMS farms in Sweden. The study includes farms with a number ranging from 58 to 175 milking dairy cows and one to three milking units. So in that aspect the study could be representative considering that the majority of AMS farms in Sweden have herds with less than 199 cows (Växa Sverige 2021). On the other hand, the farmers that are motivated to join the study could belong to a certain kind of group i.e., those who have had problems with heat stress and extreme weather before which would mean that they don´t represent the AMS farms in Sweden.

A suggestion for future research would for example be to include farm visits in the study to be able to observe differences between farms. This would make it easier to compare and categorize farms more fairly, particularly regarding pasture characteristics as access to shade, distance to pasture, cow traffic etc. Barn and pasture hygiene and cow cleanliness could also be assessed easier as it plays a central role in terms of udder health. Another suggestion could be to make an online survey instead of interviews to minimize the impact of social desirability bias.

6. Conclusions

The aim of this study was to describe the impact of summer on SCC and milking interval in farms with AMS as well as to identify factors related to pasture and udder health that could influence the mean proportional difference in SCC between winter and summer. On the included AMS farms the SCC increased, and the milking frequency decreased during the summer compared to the winter. The study also showed that herds can have small differences in mean herd SCC between winter and summer.

Further research is needed looking at characteristics and management strategies both inside the barn and on pasture to completely understand why there is the seasonal pattern with a higher SCC and lower milking frequency during the summer and what is causing it.

References

Albihn, A., Seligsohn, D., Rydhmer, L., Gunnarsson, S., Hansson, P.-A., Johnsson, P. & Kuns, B. (2021). *Klimatanpassning av svensk animalieproduktion - säkrare tillgång på livsmedel under en kris* Available at: www.slu.se/futurefood [2021-11-02]

Amaral, B.C. d., Connor, E.E., Tao, S., Hayen, J., Bubolz, J. & Dahl, G.E. (2010). Heat stress abatement during the dry period influences prolactin signaling in lymphocytes. *Domestic Animal Endocrinology*, vol. 38 (1), pp. 38–45. https://doi.org/10.1016/j.domaniend.2009.07.005

Andersson, I., Andersson, H., Christiansson, A., Oscarsson, M., Persson, Y. & Widell, A. (2011). *Systemanalys celltal.* Svensk Mjölk - Forskning, Rapport nr: 7091.

Arnott, G., Ferris, C.P. & O'Connell, N.E. (2017). Review: welfare of dairy cows in continuously housed and pasture-based production systems. *Animal*, vol. 11 (2), pp. 261–273. https://doi.org/10.1017/S1751731116001336

Bach, A. & Busto, I. (2005). Effects on milk yield of milking interval regularity and teat cup attachment failures with robotic milking systems. *Journal of Dairy Research*, vol. 72 (1), pp. 101–106. https://doi:10.1017/s0022029904000585

Bagath, M., Krishnan, G., Devaraj, C., Rashamol, V., Pragna, P., Lees, A. & Sejian, V. (2019). The impact of heat stress on the immune system in dairy cattle: A review. *Research in Veterinary Science*, vol. 126, pp. 94–102. https://doi.org/10.1016/J.RVSC.2019.08.011

Bargo, F., Muller, L.D., Delahoy, J.E. & Cassidy, T.W. (2002). Performance of high producing dairy cows with three different feeding systems combining pasture and total mixed rations. *Journal of Dairy Science*, vol. 85 (11), pp. 2948–2963. https://doi.org/10.3168/jds.S0022-0302(02)74381-6

Becker, C.A., Collier, R.J. & Stone, A.E. (2020). Invited review: Physiological and behavioral effects of heat stress in dairy cows. *Journal of Dairy Science*, vol. 103 (8), pp. 6751–6770. https://doi.org/10.3168/jds.2019-17929

Blackshaw, J. & Blackshaw, A. (1994). Heat stress in cattle and the effect of shade on production and behaviour: a review. *Australian Journal of Experimental Agriculture*, vol. 34 (2), pp. 285–295. https://doi.org/10.1071/EA9940285

Caplen, G. & Held, S.D.E. (2021). Changes in social and feeding behaviors, activity, and salivary serum amyloid A in cows with subclinical mastitis. *Journal of Dairy Science*, vol. 104 (10), pp. 10991–11008. https://doi.org/10.3168/JDS.2020-20047

Collier, R.J., Dahl, G.E. & Vanbaale, M.J. (2006). Major advances associated with environmental effects on dairy cattle. *Journal of Dairy Science*, vol. 89 (4), pp. 1244–1253. https://doi.org/10.3168/jds.S0022-0302(06)72193-2

CORDIS (2005). *Implications of the introduction of automatic milking on dairy farms*. Available at: https://cordis.europa.eu/project/id/QLK5-CT-2000-01006/results [2021-10-18]

Dahl, G.E. (2008). Effects of short day photoperiod on prolactin signaling in dry cows: A common mechanism among tissues and environments? *Journal of Animal Science*, vol. 86 (suppl_13), pp. 10–14. https://doi.org/10.2527/JAS.2007-0311

Dahl, G.E. (2018). Impact and mitigation of heat stress or mastitis control. *Veterinary Clinics of North America - Food Animal Practice*. https://doi.org/10.1016/j.cvfa.2018.07.002

DairyNZ (2021). *Milking intervals*. [Farmers industry organisation]. Available at: https://www.dairynz.co.nz/milking/milking-intervals/ [2021-10-19]

Das, R., Sailo, L., Verma, N., Bharti, P., Saikia, J., Imtiwati & Kumar, R. (2016). Impact of heat stress on health and performance of dairy animals: A review. *Veterinary World*, vol. 9 (3), p. 260. https://doi.org/10.14202/VETWORLD.2016.260-268

Dikmen, S. & Hansen, P.J. (2009). Is the temperature-humidity index the best indicator of heat stress in lactating dairy cows in a subtropical environment? *Journal of Dairy Science*, vol. 92 (1), pp. 109–116. https://doi.org/10.3168/JDS.2008-1370

Duse, A., Persson-Waller, K. & Pedersen, K. (2021). Microbial aetiology, antibiotic susceptibility and pathogen-specific risk factors for udder pathogens from clinical mastitis in dairy cows. *Animals*, vol. 11 (7) 2113. DOI: https://doi.org/10.3390/ANI11072113

Falk, A.C., Weary, D.M., Winckler, C. & von Keyserlingk, M.A.G. (2012). Preference for pasture versus freestall housing by dairy cattle when stall availability indoors is reduced. *Journal of Dairy Science*, vol. 95 (11), pp. 6409–6415. https://doi.org/10.3168/jds.2011-5208

Fogsgaard, K., Røntved, C., Sørensen, P. & Herskin, M. (2012). Sickness behavior in dairy cows during Escherichia coli mastitis. *Journal of Dairy Science*, vol. 95 (2), pp. 630–638. https://doi.org/10.3168/JDS.2011-4350

Green, M.J., Bradley, A.J., Newton, H. & Browne, W.J. (2006). Seasonal variation of bulk milk somatic cell counts in UK dairy herds: Investigations of the summer rise. *Preventive Veterinary Medicine*, vol. 74 (4), pp. 293–308. https://doi.org/10.1016/j.prevetmed.2005.12.005

Grimstedt, L. (2021). Antalet mjölkföretag under 3000. *Husdjur.* Available at: https://www.vxa.se/husdjur/nyheter/2021/antalet-mjolkforetag-under-3000/ [2021-11-11]

Halasa, T., Huijps, K., Østerås, O. & Hogeveen, H. (2011). Economic effects of bovine mastitis and mastitis management: A review. *Veterinary Quarterly*, vol. 29 (1), pp. 18–31. https://doi.org/10.1080/01652176.2007.9695224

Heutinck, L.F.M., van Dooren, H.J.C & Biewenga, G. (2004). Automatic milking and grazing in dairy cattle: Effects on behavior. In Meijering, A., Hogeveen, H. & de Koning, C.J.A.M. *Automatic milking: A better understanding*. Wageningen: Wageningen Academic Publishers. 407-413.

Jacobs, J.A. & Siegford, J.M. (2012). Invited review: The impact of automatic milking systems on dairy cow management, behavior, health, and welfare. *Journal of Dairy Science*, vol. 95 (5), pp. 2227–2247. https://doi.org/10.3168/jds.2011-4943

Jago, J., Bright, K., Copeman, P., Davis, K., Jackson, I., Ohnstad, I., Wieliczko, R. & Woolford, M. (2004). Remote automatic selection of cows for milking in a pasture-based automatic milking system. *Proceedings of the NewZealand Society of Animal Production*, Hamilton, Jan 2004, vol. 64. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1073.3532&rep=rep1&type=pdf [2021-10-19]

Jordbruksverket (2021). *Skötsel och stallmiljö*. Available at: https://jordbruksverket.se/djur/lantbruksdjur-och-hastar/notkreatur/skotsel-och-stallmiljo [2021-11-02]

Juverportalen (2021). *Gränsvärden för mjölkens celltal*. Available at: http://juverportalen.se/saa-upptaecks-mastit/graensvaerden-foer-mjoelkens-celltal/ [2022-01-08]

Kadzere, C.T., Murphy, M.R., Silanikove, N. & Maltz, E. (2002). Heat stress in lactating dairy cows: A review. *Livestock Production Science*, vol. 77 (1), pp. 59–91. https://doi.org/10.1016/S0301-6226(01)00330-X

Ketelaar-De Lauwere, C.C., Ipema, A.H., Lokhorst, C., Metz, J.H.M., Noordhuizen, J.P.T.M., Schouten, W.G.P. & Smits, A.C. (2000). Effect of sward height and distance between pasture and barn on cows' visits to an automatic milking system and other behaviour. *Livestock Production Science*, vol. 65 (1–2), pp. 131–142. https://doi.org/10.1016/S0301-6226(99)00175-X

Ketelaar-De Lauwere, C.C., Ipema, A.H., Van Ouwerkerk, E.N.J., Hendriks, M.M.W.B., Metz, J.H.M., Noordhuizen, J.P.T.M. & Schouten, W.G.P. (1999). Voluntary automatic milking in combination with grazing of dairy cows: Milking frequency and effects on behaviour. *Applied Animal Behaviour Science*, vol. 64 (2), pp. 91–109. https://doi.org/10.1016/S0168-1591(99)00027-1

Klungel, G.H., Slaghuis, B.A. & Hogeveen, H. (2000). The effect of the introduction of automatic milking systems on milk quality. *Journal of Dairy Science*, vol. 83 (9), pp. 1998–2003. https://doi.org/10.3168/JDS.S0022-0302(00)75077-6

KRAV (2021). *5.2.3 Utevistelse och bete*. Available at: https://regler.krav.se/unit/krav-article/47509bb5-809b-403b-b3ea-d0ae6a48d739 [2021-10-07]

Krömker, V. & Leimbach, S. (2017). Mastitis treatment—Reduction in antibiotic usage in dairy cows. *Reproduction in Domestic Animals*, vol. 52, pp. 21–29. https://doi.org/10.1111/rda.13032

Kuipers, A., Koops, W. & Wemmenhove, H. (2016). Antibiotic use in dairy herds in the Netherlands from 2005 to 2012. *Journal of Dairy Science*, vol. 99 (2), pp. 1632–1648. https://doi.org/10.3168/JDS.2014-8428

Van Laer, E., Tuyttens, F.A.M., Ampe, B., Sonck, B., Moons, C.P.H. & Vandaele, L. (2015). Effect of summer conditions and shade on the production and metabolism of Holstein dairy cows on pasture in temperate climate. *Animal*, vol. 9 (9), pp. 1547–1558. https://doi:10.1017/S1751731115000816

Lakic, B. (2011). *Effects of a single prolonged milking interval in cows study of indicators and mediators of inflammation, milk composition and yield.* Diss. (Acta Universitatis Agriculturae Sueciae 2011:101). Uppsala: Swedish University of Agricultural Sciences. http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-e-285

Landin, H. (2012). Samma celltal, nya bakterier? *Svensk Mjölks Djurhälso- och utfodringskonferens*, Uppsala 21-22 augusti 2012, pp. 14-16. https://www.vxa.se/globalassets/dokument/fordjupningar/dou/2012/samma-celltal---nya-bakterier.pdf

Laurs, A., Priekulis, J., development, M.P.-E. for rural & 2010, undefined (2010). Research in time between milking interval and variability of milking frequency using milking robots. *9th International Scientific Conference - Engineering for Rural Development*, Jelgava, May 27-28, 2010, pp. 101-105. Available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.612.2553&rep=rep1&type=pdf [2021-12-08]

Lievaart, J.J., Barkema, H.W., Kremer, W.D.J., Van Den Broek, J., Verheijden, J.H.M. & Heesterbeek, J.A.P. (2007). Effect of herd characteristics, management practices, and season on different categories of the herd somatic cell count. *Journal of Dairy Science*, vol. 90 (9), pp. 4137–4144. https://doi:10.3168/jds.2006-847

LRF (2021). *Självförsörjning*. Available at: https://www.lrf.se/politikochpaverkan/foretagarvillkor-och-konkurrenskraft/nationell-livsmedelsstrategi/sjalvforsorjning/ [2021-11-03]

Lyons, N.A., Kerrisk, K.L. & Garcia, S.C. (2014). Milking frequency management in pasture-based automatic milking systems: A review. *Livestock Science*, vol. 159 (1), pp. 102–116. https://doi.org/10.1016/j.livsci.2013.11.011

Mader, T.L., Fell, L.R. & McPhee, M.J. (1997). Behavior response of non-Brahman cattle to shade in commercial feedlots. *Livestock Environment*, vol. 5, pp. 792–801.

Medrano-Galarza, C., Gibbons, J., Wagner, S., de Passillé, A.M. & Rushen, J. (2012). Behavioral changes in dairy cows with mastitis. *Journal of Dairy Science*, vol. 95 (12), pp. 6994–7002. https://doi.org/10.3168/JDS.2011-5247

Mollenhorst, H., Hidayat, M., van den Broek, J., Neijenhuis, F. & Hogeveen, H. (2011). The relationship between milking interval and somatic cell count in automatic milking systems. *Journal of Dairy Science*, vol. 94 (9), pp. 4531–4537. https://doi.org/10.3168/JDS.2011-4244

Olde Riekerink, R.G.M., Barkema, H.W. & Stryhn, H. (2007). The effect of season on somatic cell count and the incidence of clinical mastitis. *Journal of Dairy Science*, vol. 90 (4), pp. 1704–1715. https://doi:10.3168/jds.2006-567

Oliver, S. & Murinda, S. (2012). Antimicrobial resistance of mastitis pathogens. *The Veterinary Clinics of North America. Food Animal Practice*, vol. 28 (2), pp. 165–185. https://doi.org/10.1016/J.CVFA.2012.03.005

Ouweltjes, W. (1998). The relationship between milk yield and milking interval in dairy cows. *Livestock Production Science*, vol. 56 (3), pp. 193–201. https://doi.org/10.1016/S0301-6226(98)00154-7

Persson, Y., Nyman, A.-K.J. & Grönlund-Andersson, U. (2011). Etiology and antimicrobial susceptibility of udder pathogens from cases of subclinical mastitis in dairy cows in Sweden. *Acta Veterinaria Scandinavica*, vol. 53, p. 36. https://doi.org/10.1186/1751-0147-53-36

Pillai, S., Kunze, E., Sordillo, L. & Jayarao, B. (2001). Application of differential inflammatory cell count as a tool to monitor udder health. *Journal of Dairy Science*, vol. 84 (6), pp. 1413–1420. https://doi.org/10.3168/JDS.S0022-0302(01)70173-7

van den Pol-van Dasselaar, A., van den Heiligenberg, H., Vellinga, T.V., Johansen, A. & Kennedy, E. (2008). To graze or not to graze, that's the question. *Grassland Science in Europe*, vol. 13, 706-716. Available at: https://www.europeangrassland.org/fileadmin/documents/Infos/Printed_Matter/Proceedings/EGF2008.pdf [2021-11-03]

Pyörälä, S. (2003). Indicators of inflammation in the diagnosis of mastitis. *Veterinary Research*, vol. 34 (5), pp. 565–578. https://doi:10.1051/vetres:2003026

Rakib, M.R.H., Zhou, M., Xu, S., Liu, Y., Khan, M.A., Han, B. & Gao, J. (2020). Effect of heat stress on udder health of dairy cows. *Journal of Dairy Research*, vol. 87 (3), pp. 315–321. https://doi.org/10.1017/S0022029920000886

Riley, D.G., Chase, C.C., Coleman, S.W. & Olson, T. (2012). Genetic assessment of rectal temperature and coat score in Brahman, Angus, and Romosinuano crossbred and straightbred cows and calves under subtropical summer conditions. *Livestock Science*, vol. 148 (1–2), pp. 109–118. https://doi.org/10.1016/j.livsci.2012.05.017

Schukken, Y.H., Weersink, A., Leslie, K.E. & Martin, S.W. (1993). Dynamics and regulation of bulk milk somatic cell counts. *Canadian Journal of Veterinary Research*, vol. 57 (2), p. 131. Available at: /pmc/articles/PMC1263607/?report=abstract [2021-09-13]

Schukken, Y.H., Wilson, D.J., Welcome, F., Garrison-Tikofsky, L. & Gonzalez, R.N. (2003). Monitoring udder health and milk quality using somatic cell counts. *Veterinary Research*, vol. 34 (5), pp. 579–596. https://doi.org/10.1051/VETRES:2003028

Schütz, K.E., Cox, N.R. & Tucker, C.B. (2014). A field study of the behavioral and physiological effects of varying amounts of shade for lactating cows at pasture. *Journal of Dairy Science*, vol. 97 (6), pp. 3599–3605. https://doi.org/10.3168/jds.2013-7649

Schütz, K.E., Rogers, A.R., Poulouin, Y.A., Cox, N.R. & Tucker, C.B. (2010). The amount of shade influences the behavior and physiology of dairy cattle. *Journal of Dairy Science*, vol. 93 (1), pp. 125–133. https://doi.org/10.3168/jds.2009-2416

Schwarz, D., Kleinhans, S., Reimann, G., Stückler, P., Reith, F., Ilves, K., Pedastsaar, K., Yan, L., Zhang, Z., Valdivieso, M., Barreal, M.L. & Fouz, R. (2020). Investigation of dairy cow performance in different udder health groups defined based on a combination of somatic cell count and differential somatic cell count. *Preventive Veterinary Medicine*, vol. 183, p. 105123. https://doi.org/10.1016/j.prevetmed.2020.105123

Seegers, H., Fourichon, C. & Beaudeau, F. (2003). Production effects related to mastitis and mastitis economics in dairy cattle herds. *Veterinary Research*, vol. 34 (5), pp. 475–491. https://doi.org/10.1051/VETRES:2003027

SFS 2019:66. *Djurskyddsförordning*. Näringsdepartementet. Available at: https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/djurskyddsforordning-201966_sfs-2019-66 [2021-10-07]

Siivonen, J., Taponen, S.S., Hovinen, M., Pastell, M., Lensink, J., Pyörälä, S. & Hänninen, L. (2011). Impact of clinical acute mastitis on cow behaviour. *Applied Animal Behaviour Science*, vol. 132 (3–4), pp. 101–106. https://doi.org/10.1016/J.APPLANIM.2011.04.005

SMHI (2021a). *Extremt väder*. Available at: https://www.smhi.se/kunskapsbanken/klimat/extremer/extremt-vader-1.5779 [2022-01-03]

SMHI (2021b). *Så påverkar värmen våra mjölkkor*. Available at: https://www.smhi.se/kunskapsbanken/sa-paverkar-varmen-vara-mjolkkor-1.138977 [2021-10-12]

Spörndly, E. & Wredle, E. (2004). Automatic milking and grazing--effects of distance to pasture and level of supplements on milk yield and cow behavior. *Journal of Dairy Science*, vol. 87 (6), pp. 1702–1712. https://doi.org/10.3168/JDS.S0022-0302(04)73323-8

Spörndly, E. & Wredle, E. (2005). Automatic milking and grazing--effects of location of drinking water on water intake, milk yield, and cow behavior. *Journal of Dairy Science*, vol. 88 (5), pp. 1711–1722. https://doi.org/10.3168/JDS.S0022-0302(05)72844-7

SVA (2021). *Mastit hos mjölkkor*. Available at: https://www.sva.se/amnesomraden/djursjukdomar-a-o/mastit-hos-mjolkkor/ [2021-10-28]

SVS (Sveriges Veterinärmedicinska Sällskap, Husdjurssektionen) (2019). *Riktlinjer för antibiotikaanvändning till nötkreatur och gris.* Available at: https://www.svf.se/media/ewnnbbpi/svfs-riktlinje-g%C3%A4llande-n%C3%B6tkreatur-och-gris-2015.pdf

Tao, S., Orellana, R.M., Weng, X., Marins, T.N., Dahl, G.E. & Bernard, J.K. (2018). Symposium review: The influences of heat stress on bovine mammary gland function1. *Journal of Dairy Science*, vol. 101 (6), pp. 5642–5654. https://doi.org/10.3168/JDS.2017-13727

Tao, S., Orellana Rivas, R.M., Marins, T.N., Chen, Y.C., Gao, J. & Bernard, J.K. (2020). Impact of heat stress on lactational performance of dairy cows. *Theriogenology*, vol. 150, pp. 437–444. https://doi.org/10.1016/j.theriogenology.2020.02.048

Tucker, C.B., Rogers, A.R. & Schütz, K.E. (2008). Effect of solar radiation on dairy cattle behaviour, use of shade and body temperature in a pasture-based system. *Applied Animal Behaviour Science*, vol. 109 (2–4), pp. 141–154. https://doi.org/10.1016/j.applanim.2007.03.015

Vassarstats (2021a). *Mann-Whitney Test.* Available at: http://vassarstats.net/ [2021-12-

07]

Vassarstats (2021b). *Kruskal-Wallis Test.* Available at: http://vassarstats.net/ [2021-12-07]

Växa Sverige (2017). *Cattle statistics 2017.* Available at: https://www.vxa.se/globalassets/dokument/statistik/husdjursstatistik_2017.pdf [2021-12-07]

Växa Sverige (2018). *Cattle statistics 2018.* Available at: https://www.vxa.se/globalassets/dokument/statistik/husdjursstatistik-2018.pdf [2021-12-07]

Växa Sverige (2019). *Cattle statistics 2019.* Available at: https://www.vxa.se/globalassets/dokument/statistik/husdjursstatistik-2019.pdf [2021-12-07]

Växa Sverige (2020a). *Antibiotikastatistik 2020, Förskrivning av antibiotika i svenska mjölkkobesättningar, 2001–2020.* Available at: https://www.vxa.se/globalassets/dokument/statistik/antibiotikastatistik-2001-2020.pdf [2021-10-28]

Växa Sverige (2020b). *Manual for Livestock Keepers within Milk Production.* Available at: https://www.vxa.se/globalassets/dokument/fordjupningar/info-pa-flera-sprak/manual_for_livestock_keepers_english.pdf [2022-01-08]

Växa Sverige (2020c). *Cattle health statistics 2019/2020*. [In Swedish: Djurhälsostatik 2019-2020] Available at: https://assets.adobe.com/public/abadfce8-53e4-48d4-744d-d136503b81a4 [2022-01-08]

Växa Sverige (2021). *Cattle statistics 2021*. Available at: https://www.vxa.se/globalassets/dokument/statistik/husdjursstatistik-2021.pdf [2021-10-20]

Washburn, S.P., White, S.L., Green, J.T. & Benson, G.A. (2002). Reproduction, mastitis, and body condition of seasonally calved Holstein and Jersey cows in confinement or pasture systems. *Journal of Dairy Science*, vol. 85 (1), pp. 105–111. https://doi.org/10.3168/jds.S0022-0302(02)74058-7

Wiktorsson, H. & Spörndly, E. (2002). Grazing: an animal welfare issue for automatic milking farms. *Section: Labour, economics and animal welfare of The First North American Conference on Robotic Milking* - March 20-22, 2002, Toronto, Canada, pp. VI32-VI43. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.518.2053&rep=rep1&type=pdf

Wredle, E. (2005). *Automatic Milking and Grazing - Factors and Stimuli Affecting Cow Motivation to Visit the Milking Unit.* Diss. (Acta Universitatis Agriculturae Sueciae 2005:116) Uppsala: Swedish University of Agricultural Sciences. Available at: http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-812

Yousef, M. (1985). *Stress Physiology in Livestock, Vol. 1: Basic Principles,* 1st Edition. Boca Raton Fla.: CRC Press.

Thank you

I would like to thank my supervisor Lena-Mari for the all the invaluable help and cheer on along the way. I would also like to thank Elna för a good collaboration during the collection and compilation of the data. Lastly, I would like to thank you all the farmers that participated in this study.

Populärvetenskaplig sammanfattning

Juverhälsa hos mjölkkor spelar en central roll inom mjölkindustrin. En försämrad juverhälsa kan både innebära negativa konsekvenser ekonomiskt och för djurvälfärden samt bidra till ökad användning av antibiotika. En höjning av celltalet (en vanlig mätmetod för juverhälsa som kan mätas i kornas mjölk, ju högre celltal desto sämre juverhälsa) har i tidigare studier observerats under sommarmånaderna, både i Sverige och internationellt. I Sverige finns det krav på bete för mjölkkor, vilket innebär att de under sommarmånaderna enligt lag ska vara ute på bete en del av dygnet. Under varma sommardagar kommer korna att utsättas för värme som bland annat tros bidra till celltalshöjningen. Det finns ett ökande behov av att försöka förebygga eller minska värmens påverkan på mjölkkorna under sommaren dels på grund av den globala uppvärmningen och de ökande temperaturerna, dels på grund av känsligheten hos framför allt de högproducerande mjölkkorna.

Syftet med den här studien var att undersöka varmare perioders påverkan på celltal och mjölkningsfrekvens på gårdar med ett automatiskt mjölkningssystem (ett system där korna mjölkas automatiskt av en mjölkrobot som de besöker frivilligt). Syftet var även att utforska olika beteskännetecken och skötselstrategier på dessa gårdar och se hur dessa påverkar möjligheten att upprätthålla en god juverhälsa under varmare perioder och betessäsongen.

Den här studien är baserad på 26 telefonintervjuer med lantbrukare som har ett automatiskt mjölkningssystem. Intervjun inkluderade frågor om deras beten, foder, juverhälsa med mera med fokus på lantbrukarnas erfarenheter och rutiner under sommarmånaderna. Mjölkgårdarna valdes ut baserat på data från 2017–2019 från svenska mjölk och sjukdomsregistret och inkluderade gårdar som ökade i celltal och de som inte påverkades lika mycket. Svaren analyserades sedan med hjälp av två statistiska test för att se om skillnaden mellan de som besvarat frågorna faktiskt var en signifikant skillnad eller om det bara var en slump.

I studien hittades en säsongsbunden skillnad mellan vinter och sommar med avseende på både celltal och mjölkningsfrekvens (antalet gånger korna besöker mjölkroboten per dygn, ett högt intervall är önskvärt), celltalet ökade medan mjölkningsfrekvensen minskade under sommaren. Detta betyder att studien visade att när korna blir utsläppta på bete på sommaren så försämras deras juverhälsa och de besöker mjölkroboten färre gånger per dygn. Vissa gårdar väljer att begränsa vattentillgången för korna till enbart inomhus för att få de att gå och besöka mjölk-roboten oftare och på så sätt få ett högre mjölkningsfrekvens. Det här visade sig inte ha någon effekt på mjölkningsfrekvens i studien, utan det var ingen skillnad i frekvens mellan de gårdar som hade vatten på bete och inomhus jämfört med de som bara hade vatten inomhus. Resultaten visade även att kor med fri tillgång till betet hade en lägre mjölkningsfrekvens jämfört med de kor som hade en begränsad tillgång.

Det är svårt att dra några slutsatser från studien, annat än att celltalet ökade och mjölkningsfrekvensen minskade på sommaren på de inkluderande gårdarna. Genom att studera celltalet och mjölkningsfrekvensen på de inkluderade gårdarna går det att se att vissa kunde bibehålla det under sommaren. Vidare forskning behövs för att titta närmre på egenskaper och skötselrutiner både inne i ladugården och på betet för att helt förstå varför det finns ett säsongsbundet mönster med ett högre celltal på sommaren.

Appendix 1

The questions marked with a green colour were used in the present study.

1. Allmänna uppgifter

Datum

____

Ifylld av

Telefonnummer

____

Gårdsnamn

____

SE-nummer

____

Namn

____

2. Upplevelser av extremvärme

Upplevde du att dina kor blev varma i somras? Om ja, när?

Nej

Ja, när?

____

Hur såg du att dina kor var varma?

____

Har du använt någon strategi för att minska effekten av värme i år?

Nej

Ja, vilken?

____

Vad gör du annorlunda en riktigt varm dag (jämfört med "vanliga" dagar)?

____

Hur länge vill du kunna utfodra med fjolårets skörd? (Dvs hur mycket buffert vill du ha i den bästa av världar)

____

Hur länge utfodrade du med fjolårets skörd i år?

____

Hur länge hade du kunnat utfodra med fjolårets skörd?

____

Vilken har varit din största utmaning i vår/sommar?

____

Upplever du att det är svårare att hinna med de dagliga rutinerna i stallet under sommaren? Om ja på vilket sätt?

Nej

Ja ________________________________

3. Bete

Frågorna gäller mjölkande kor under juli och augusti

Vilken typ av bete har korna?

Rastbete

Produktionsbete

Blandning

Finns skugga på betet?
Ja, flera ställen (ex naturbete)
Delvis
Enstaka ställen
Ingen

Hur långt är det mellan betet/betena och ladugården?

____

Uppskatta andel grovfoder korna får i sig på bete (i juli, %)

____

Har korna:
Fri tillgång till bete
Tillgång under dagen
Tillgång under natten
Ute dagtid (utan tillgång till ladugård)
Ute nattetid (utan tillgång till ladugård)
Vilka tider av dygnet har djuren tillgång till bete? (Klockslag)

____

När släppte du ut korna i år?

____

Var detta
som vanligt
senare än vanligt
tidigare än vanligt

När tar du normalt in korna?

____

Har du någon betesstrategi för att bibehålla mjölkproduktionen under sommaren?
Nej
Ja, vilken?

____

4. Ventilation och kylning

Kan du justera/styra ventilationen i ladugården?
Ja
Delvis
Nej
Kommentar

____

Kan du få bra vinddrag genom byggnaden där korna vistas?
1 Ja, oftast
2
3
4
5 Det varierar
6
7
8
9
10 Nej, väldigt svårt/sällan
Kommentar

____

Hur fungerar det att ströa under sommarhalvåret med tanke på vinddraget?
Ingen skillnad
Ströar mindre än vanligt
Undviker strö vid blåst
Kommentar

____

Strategier för att hålla temperaturen nere? (kryssa alla som används)
Genomdrag
Justera ventilation
Blötläggning (med slang)
Blötläggning (sprinkler/dusch)
Fläktar
Nattbete

Annan betesstrategi

____

Om fläkt, vilken tillverkare?

____

Hur många fläktar finns och hur är de fördelade i ladugården? I vilket väderstreck ligger de i?

____

Under vilken tidsperiod går fläktarna på maxeffekt?

____

Vid (ungefär) vilken temperatur uppstår problem hos dig? (grader)

____

5. Vatten

Upplever du att korna har tillräcklig tillgång till vatten?
I stallet:
1 Ja
2
3 Varierar
4
5 Nej

Upplever du att korna har tillräcklig tillgång till vatten?
På bete:
1 Ja
2
3 Varierar
4
5 Nej
Har inte vatten på bete

När uppstår problem med vattentillgång för dig?

____

När gör du rent vattenkoppar/kar?
I lösdriften:

____

När gör du rent vattenkoppar/kar?
På bete:

____

Upplever du någon skillnad i vattenkvalité på sommaren? Om ja på vilket sätt?
Nej
Vet inte
Ja ______________________________

För gårdar med egen brunn:
God Okej
Sämre än
önskat Dålig Vet inte
Hur är
vattentillgången
just nu?
Hur är den
hygieniska
vattenkvalitén
just nu?

6. Antal djur + KRAV/eko

Antal mjölkande

____

Antal övriga nötkreatur (i lösdriften)

____

Totalantal djur på gården

____

Är din besättning ekologisk och/eller KRAV-certifierad?
Nej
Ja, vilken/vilka?

____

7. Utfodring

Hur ofta blandar du foder? (xx ggr per dag/vecka/vid behov)

____

Blandar du annorlunda på sommaren (jämfört med vintern)?
Nej
Oftare
Mer sällan
Ja, på vintern blandar jag:
____

Med vilka tidsintervall får korna nytt foder på foderbordet?
____

Ändrar du intervallet på sommaren (jämfört med vintern)?
Nej
Oftare
Mer sällan
Ja, på vintern får korna nytt foder:
____

Har du gjort några ändringar/tillägg i foderstaten under/inför sommaren?
Nej
Ja ___________________________________

Upplever du att korna minskar sitt foderintag under sommaren?
Nej
Ja, av grovfoder
Ja, av kraftfoder
Ja, av både kraftfoder och grovfoder

Gör du några förebyggande/akuta åtgärder för att upprätthålla foderintag under varma perioder?
Nej
Ja ___________________________________

Målavkastning för 1a kalvare (med utfodring 1 mån efter kalvning)
____

Målavkastning för äldre djur (med utfodring 1 mån efter kalvning)
____

Uppskatta hur mycket salt det går åt på en vecka?
____

Finns det en analys på det grovfoder som korna ätit den senaste veckan?
Ja
Nej

8. Reproduktion och fertilitet

Hur många kor har inseminerats senaste två veckorna?
____

Hur många kor har inseminerats de senaste två veckorna? Uppskatta andel djurägarsemin (%)
____

Hur många kor har inseminerats de senaste två veckorna? Uppskatta andel betäckt med tjur (%)
____

Hur många kor har inseminerats de senaste två veckorna? Uppskatta andel assistentsemin (%)
____

Hur har brunstpassning gjorts under sommaren?
Manuell observation
Automatisk, sensortyp:
____

Om manuell brunstpassning: När har brunstpassning utförts i sommar?
Fasta tider
Löpande under arbetet med djuret
Annat:
____

Om fasta tider, hur många gånger per dag eller vecka?

____

Vid inseminering, i hur stor utsträckning förlitar du dig på...
1 Låg grad 2 3 Delvis 4
5 Mkt hög
grad
Manuell
observation av
brunsttecken
Aktivitetsmätare
Tid sedan
senaste brunst

På sommaren (juli/augusti) seminerar jag:
kvigor
fler än vanligt
lika många (som "vanligt")
färre än vanligt

Hämtas kvigor in från bete inför seminering?
Nej, de är på plats
Nej, använder tjur
Ja

Om kvigor hämtas in, när släpps de ut på bete igen?
Efter seminering
efter dräktighetsundersökning
annan lösning

____

Min strategi för seminering av kvigor under sommartid är:

____

Har du någon särskild strategi för val av tjur vid semin (exempelvis egenskap eller ursprung)?

____

9. Typ av mjölkning
Typ av mjölkning
AMS
Konventionell

10. Mjölkning AMS
Genomsnittligt mjölkningsintervall under betesperioden (från roboten)?

____

Antal kor som hämtas till mjölkning/dag i sommar, i genomsnitt (från roboten)?

____

Mjölkningar/ledig tid (%)

____

Andel misslyckade/ofullständiga mjölkningar (från roboten)?

____

Har du någon kylning i roboten?
Nej
Ja, fläkt
Ja, genomdrag
Annat:

____

Upplever du färre mjölkningar per ko på sommaren?
Ja
Nej

Förebygger/agerar du för att förhindra ökade mjölkningsintervall på sommaren?
Nej
Ja, vad gör du?

____

Har du någon strategi för att locka in korna från bete?
Nej
Ja, vilken?

____

11. Mjölkning konventionell

Antalet mjölkningar per dygn:

2

3

Annat:

____

Tid för mjölkning (från-till) på fm

____

Tid för mjölkning (från-till) på em

____

Tid för mjölkning (från-till) vid ev. tredje mjölkning

____

Har du någon kylning i väntafållan/innan mjölkning?

Nej

Ja, fläkt

Ja, genomdrag

Ja, dusch/sprinkler

Ja, blötlägger med vattenslang

Annat:

____

Har du någon kylning under mjölkningen?

Nej

Ja, fläkt

Ja, genomdrag

Annat:

____

Hur fungerar de vanliga mjölkningsrutinerna under sommaren?

1 Väldigt dåligt

2

3

4

5

6

7

8

9

10 Väldigt bra

Vilka rutiner är svårast att upprätthålla?

____

Kyler du korna innan mjölkning?

Ibland (vid behov)

Nej, aldrig

Ja, alltid. Hur?

____

Upplever du att korna blir varma i väntfållan?

Ja

Ibland

Nej

Har du hunnit byta spengummi i tid under hela sommaren?

Ja

Nej

Osäker

12. Juverhälsa

Har du haft mastiter senaste månaden som behandlats av DÄ eller vet?

Nej

Ja, hur många?

____

Har du haft subkliniska mastiter den senaste månaden (nya djur med höga celltal). Ingen strikt detektionsgräns,

bara om DÄ har noterat ökning hos en individ)

Nej

Ja, hur många?

____

Vilken är den vanligaste bakterien som orsakat mastit den senaste månaden?

____

Upplever du ett annorlunda mönster av mastiter på sommaren?

Nej

Ja, på vilket sätt?

____

Övervakas celltalet på individnivå kontinuerligt på något annat sätt än provmjölkningen? Om ja på vilket sätt?

Nej

Ja _______________________________

Appendix 2

Farm	2017		2018		2019	
	Winter	***Summer***	***Winter***	***Summer***	***Winter***	***Summer***
1	137	142	128	315	144	135
2	183	285	249	174	268	272
3	295	285	403	282	322	333
4	244	378	336	335	436	353
5	250	251	309	221	189	275
6	336	90	131	529	211	597
7	84	228	122	199	101	137
8	183	243	157	187	125	236
9	224	229	73	124	109	141
10	234	309	199	182	206	161
11	160	289	267	256	319	451
12	226	222	317	242	274	330
13	144	176	139	135	137	116
14	390	257	380	493	397	468
15	181	201	126	289	200	216
16	224	278	190	139	186	200
17	288	460	379	355	503	502
18	176	143	166	182	98	107
19	222	273	239	341	187	247
20	268	294	188	186	244	364
21	283	423	184	346	171	406
22	139	240	207	197	236	190
23	67	137	97	142	90	206
24	148	114	132	94	98	324
25	132	240	164	312	246	277
26	91	298	128	208	273	267