Factors impacting dairy cows milk production during hot summers

– investigating the impact of the heat wave 2018 on 30 Swedish dairy farms

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Amanda Jacobsson

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Swedish University of Agricultural Sciences, SLU
Department of Animal Nutrition and Management
Agriculture programme -Animal Science
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Amanda Jacobsson

Supervisor:	**Lena-Mari Tamminen, SLU, Department of clinical sciences**
Examiner:	**Karin Alvåsen, SLU, Department of clinical sciences**

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Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science
Department of Animal Nutrition and Management

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Abstract

Heat stress in a dairy cow is defined by an increased body temperature leading to decreased welfare and productivity. The increasing number of high producing dairy cows with high vulnerability to heat, in combination with the predicted increase in temperature across the world leads to an urgent need for practical methods to reduce heat stress within the dairy industry. Since the summer of 2018 was exceptionally warm in Sweden, many Swedish dairy herds got considerably affected with lowered milk production compared to a normal summer. Therefore, the aim of this study was to investigate how factors related to housing, preventive measures and experiences influenced milk production during warm periods. Further, the goal was to identify solutions with most potential to counteract the negative effects of warm summer weather in Sweden.

The study is based on 30 phone interviews which included questions focusing on the farmer's experience of extreme weather and the consequences, housing design, systems, and routines. Risk factors were analyzed using the Mann-Whitney test. Selection of farms for the interviews was based on information from the Swedish milk and disease recording system (SMDRS), including both farms that were negatively affected by the summer 2018 (cases) and farms that were less affected (controls). Information from monthly test-milking occasions was used to calculate the proportional difference in milk production, expressed as energy corrected milk (ECM), between different time periods. First, the production during the warmest period of the summer of 2018 was compared to an average of the previous 7 months and secondly to the production during the corresponding months in 2017.

No significant difference was found regarding year of construction, housing system and ventilation system when analyzing the factors separately. However, the most common combination of these factors was used to create a category of farmers having modern warm housings with controlled ventilation. This combination of factors proved to be the most successful system for maintaining milk production during the summer with a significant difference (1.5% average increase compared to 6% decrease for the other system combinations). Regarding milking system and preventive measures, no results with significant difference could be found. However, although not significant the five farms using extra fans as a preventive measure appeared to have an advantage as they had an average increased milk production of 4% compared to 8% decrease for farms using other preventive measures. Observing early signs of heat stress in form of panting showed to have a positive impact on the milk production, with a significant difference (average 6.5% increase compared to 6% decrease for the other signs). Overall, the result from this study shows that factors have different impact on different farms, meaning that the best solution seems to be different for every farm based on their prerequisites.

Keywords: Dairy cow, Milk production, Heat stress, Interviews, Housing and systems, Management, Preventive measures

Sammanfattning

Värmestress hos mjölkkor definieras av en ökad kroppstemperatur som leder till minskad välfärd och produktivitet. Det ökande antalet högproducerande mjölkkor med hög känslighet mot värme i kombination med den förväntade temperaturökningen i världen leder till ett akut behov av praktiska metoder för att minska värmestressen inom mjölkindustrin. Då sommaren i Sverige 2018 var ovanligt varm drabbades många svenska mjölkbesättningar i större utsträckning av minskad mjölkproduktion jämfört med en vanlig sommar. Syftet med denna studie var därför att undersöka hur faktorer relaterade till inhysningssystem, förebyggande åtgärder och erfarenheter påverkade mjölkproduktionen under varma perioder. Vidare var målet att identifiera lösningar med störst potential att motverka sommarens negativa effekter i Sverige.

Studien bestod av 30 intervjuer som inkluderade frågor med fokus på lantbrukarens upplevelse av extremväder och dess konsekvenser, byggnader, system och rutiner. Baserat på intervjun valdes faktorer att undersöka och analysera med Mann-Whitney. Urvalet av gårdar för intervjuerna baserades på information från det svenska mjölk- och sjukdomsregistreringssystemet (SMDRS) och inkluderade både gårdar som påverkades negativt av sommaren 2018 (fall) samt gårdar som inte påverkades (kontroller). Information från månadsvis provmjölkning presenterades som energikorrigerad mjölk (ECM) och jämfördes med proportionell skillnad, vilket visar minskningen i mjölk mellan två perioder i procent. Den varmaste perioden sommaren 2018 jämfördes med de föregående 7 månaderna samt med samma tidsperiod under 2017.

Ingen signifikant skillnad hittades när det gäller byggår, inhysningssystem och ventilationssystem när man analyserade faktorerna separat. Den vanligaste kombinationen av dessa faktorer skapade dock en kategori av gårdar som hade moderna varma byggnader med kontrollerad ventilation. Denna kombination av faktorer visade sig vara det mest framgångsrika systemet för att upprätthålla mjölkproduktionen under sommaren med en signifikant skillnad (1,5% genomsnittlig ökning jämfört med 6% minskning för de andra systemkombinationerna). När det gäller mjölkningssystem och förebyggande åtgärder kunde inga resultat med signifikanta skillnader identifieras. Dock observerades en klar fördel för de fem gårdarna med extra fläktar som förebyggande åtgärd, med en genomsnittlig ökad mjölkproduktion på 4% jämfört med 8% minskning för de andra åtgärderna. Observation av tidiga tecken på värmestress i form av flämtning visade sig ha en positiv inverkan på mjölkproduktionen, med en signifikant skillnad (i genomsnitt 6,5% ökning jämfört med 6% minskning för de andra tecknen). Sammantaget visar resultaten från denna studie att faktorer har olika inverkan på olika gårdar, vilket innebär att den bästa lösningen verkar skilja sig mellan gårdar baserat på deras förutsättningar.

Nyckelord: Mjölkko, Mjölkproduktion, Värmestress, Intervjuer, Byggnader och system, Skötsel, Förebyggande åtgärder

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1. Introduction

The summer of 2018 in Sweden was exceptional, with a long period of high temperatures and a small amount of rain. Some parts of Sweden reached the warmest temperature sine the Swedish Meteorological and hydrological institute (SMHI) began their measurements 1961 (Sjökvist et al. 2019). This affected the whole society, including the livestock farmers and their animals. Among most dairy herds, this resulted in higher levels of somatic cells, lowered milk production and a higher degree of slaughter, compared to a normal summer (Gustafsson 2019). Due to the climatic changes, this kind of extreme heat may occur more frequently in the future. According to a study, a reduction of reoccurrence time for extreme heat from 20 year to 5 year in 20171-2100 in Scandinavia may be expected (Nikulin et al. 2009). Furthermore, the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report identified the “likely range” of increase in global average surface temperature between 0.3 °C and 4.8 °C by the year 2100 (IPCC 2014).

High milk production increases metabolic activity, which in turn generates more heat. Thus, high producing dairy cows are more sensitive to heat stress (National Research Council 1981). The increasing number of high producing dairy cows with higher vulnerability to heat in combination with the predicted increase in temperature across the world, leads to an urgent need for practical methods to reduce heat stress in the dairy industry (West 2003). Methods to reduce heat stress include physical modification of the environment, genetic development by breeding and with nutritional modification (National Research Council 1981). This thesis will investigate the effects on modification of the environment in the form of housing and systems, as well as management and routines to counteract the effects of heat stress.

This thesis was part of a larger study where the goal was to identify factors with the most impact on climatic stress by selecting both farms negatively affected and farms resilient to the extreme heat during 2018 for investigation. In association with the larger study, this thesis was based on interviewing the selected dairy farms, in order to determine and examine different housing, herd characteristics and management routines.

1.1. Aim and hypotheses

The aim of this study was to investigate how factors related to housing, preventive measures and the farmers experiences of warm cows influenced milk production during warm periods in Sweden. To achieve this the warmest period of the summer of 2018 was compared to the previous 7 months and the same time during 2017. The goal was to identify the optimal solutions, with most impact and resilience to counteract the negative effects of hot summer weather in Sweden.

The main hypothesis was that parameters as year of construction, housing type, ventilation system and milking system were expected to impact the degree of heat stress and consequently the milk production. The second hypothesis was that the use of extra fans during warm periods was the most efficient way to reduce the effect of heat stress on milk production. Lastly, the third hypothesis was that farmers observing the early signs of heat stress or experience cows as warm and act preventative were better at handling the effects of heat stress on milk production.

2. Literature

2.1. Heat stress

Heat stress is defined by an increase of internal and external heat energy causing an increase in body temperature, which induces physical and behavioural responses in the animal (Dikmen & Hansen 2009). These responses are the cow's attempt to maintain constant body temperature. When the animal is unable to dissipate enough heat, they enter a state of heat stress which further results in decreased welfare and productivity (Fournel et al. 2017).

2.1.1. Thermoneutral zone

The thermoneutral zone (TNZ) is defined as the range of ambient temperature an animal requires to attain the least amount of thermoregulatory effort, meaning minimal physiological costs and maximum productivity (Kadzere et al. 2002). The dairy cows TNZ ranges from 16 to 25 C, within which they can maintain a physiological body temperature of 38.4 to 39.1 C (Das et al. 2016).

As shown in Figure 1, below the lower critical temperature (LCT) the cow increases its heat production to maintain thermal balance, while at the upper critical temperature (UCT) responses activates to decrease the cow's heat load. Above the UCT the responses are not adequate, resulting in raised body temperature, which consequently leads to increased heat production rate (Kadzere et al. 2002).

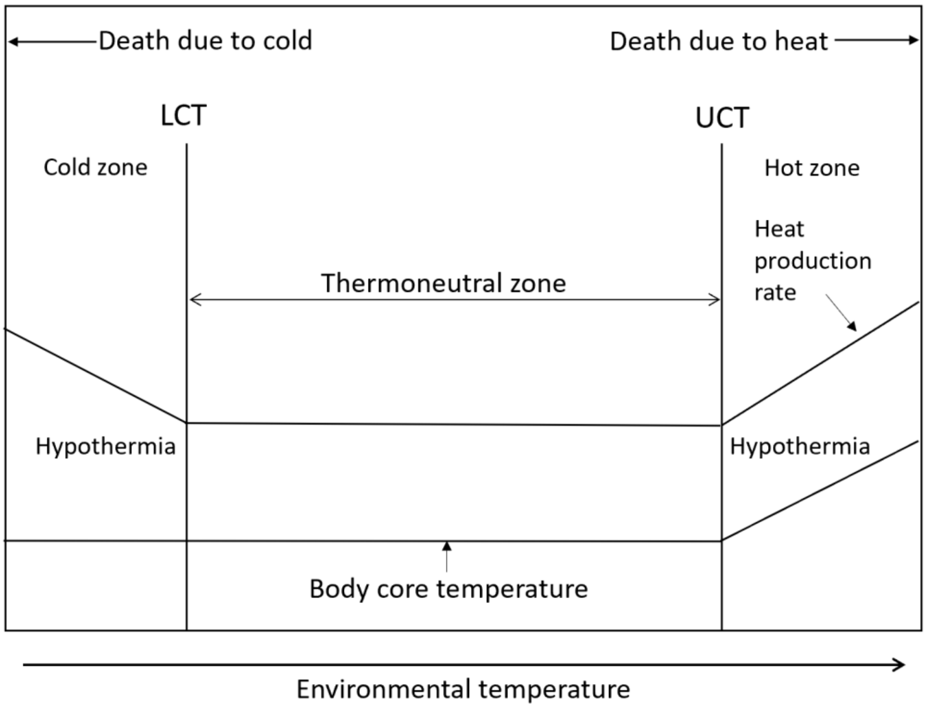

Figure 1. Schematic relationship of TNZ and the cow's body core temperature, heat production and environmental temperature. LCT, lower critical temperature; UCT, upper critical temperature Modified from Kadzere et al. (2002)

The TNZ range from LCT to UCT depends on variables such as age, breed, feed intake, production, housing conditions, stage of lactation and the cow's heat and water balance (Tao et al. 2018). Furthermore, a cow is more sensitive to heat stress and the UCT is lower during the early stage of the lactation (Tao et al. 2018). A study by Purwanto et al. (1990) compared the internal heat production of lactating and non-lactating cows. The results showed that high-yielding cows producing 31.6 kg milk/day had 48.5% higher heat production, and cows producing 18.5kg milk/day had 27.3% higher heat production, compared to non-lactating cows. Since high-producing cows have a greater internal heat production, they are also more susceptible to heat stress, resulting in a lower UCT, compared to low-producing cows (National Research Council 1981; Kadzere et al. 2002). On the other hand, this is an advantage during cold conditions since their LCT is lower, due to the extra internal heat production (National Research Council 1981).

TNZ is dynamic and the physiological and behavioural responses can be impacted by the cow's genotype and the mitigation strategies (Ji et al. 2020). Therefore, thermal stress in form of sudden or acute heat stress can be more difficult to handle for cows in the temperate regions, since the animals have not adapted physiologically to the heat stress conditions (Ominski et al. 2002).

2.1.2. Heat exchange between environment and cow

As explained by Collier et al. (2019), there is a constant exchange of energy between the animal and its environment. However, this consecution of heat exchange is lost when the thermal environment matches or exceeds the cow's body temperature, which consequently may lead to heat stress. In terms of heat stress, environmental factors relevant for the heat gain consists of four environmental variables: 1) ambient temperature, 2) solar radiation and radiation from surrounding, 3) relative humidity and 4) wind speed/air movement.

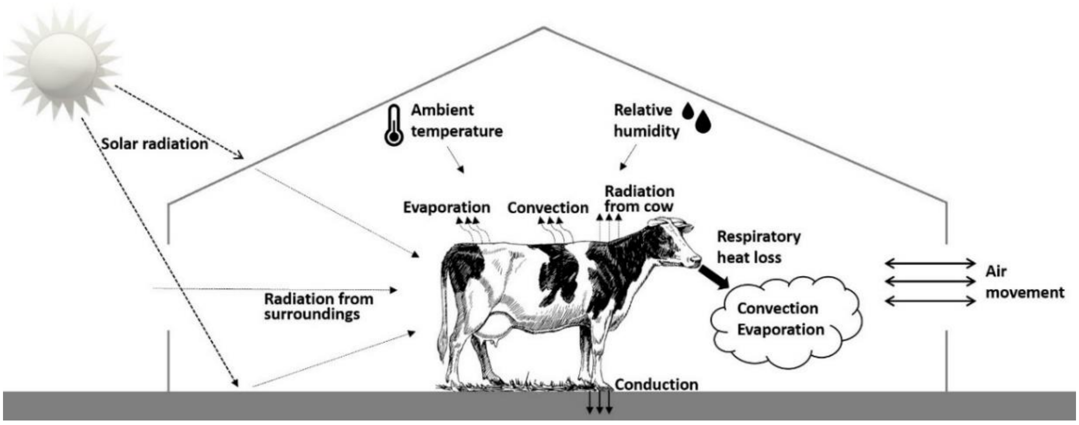

Figure 2. Illustration of the heat exchange between a housed cow and the environment. Modified from Wang et al. (2018).

During short term or acute heat stress a cow loses excessive heat according to four general thermodynamic principles of heat transfers. As shown in Figure 2, this concludes of; conduction, convention, evaporation and radiation (Ji et al. 2020). Conduction is the heat transfer between surfaces where heat is exchanged from higher temperature to lower temperate. Convection is heat loss by air flowing over the surface of the cow, which means it is also driven by temperature gradients (Collier & Gebremedhin 2015). Furthermore, convection is dependent by wind speed, meaning that it is more efficient when there is more air movement or wind speed (Ji et al. 2020). Evaporation is heat loss through fluid or water vapor that evaporates from the skin surface or the lungs, making the surface cooler (Collier & Gebremedhin 2015). Radiation heat exchange is absorption or emission of infrared radiation between two bodies. The amount of radiant absorbed depends on the temperature difference between the bodies, but also the colour and texture (Kadzere et al. 2002).

2.2. Response to heat stress

To minimize the impact of being overheated, animals have developed both physiological and behavioural coping mechanisms in form of responses. As explained by Collier et al. (2019), these responses are characterized as acclimatization, acclimation and adaptation. Acclimatization is a response to acute or short-term heat stress while acclimation is a phenotypic response, developed by day length. It prepares the animal for seasonal adjustments in insulation (ex. coat thickness), feed intake or reproductive activity (Collier et al. 2019). Due to acclimation, the TNZ for the cow changes as much as 15°C downward during winter season (National Research Council 1981). Adaption is the changes in the genotype, developed over generations where a stressful heated environment becomes permanent (Collier et al. 2019).

This thesis is about acute or short-term heat stress and will therefore focus on acclimatization. Acclimatization is driven by homeostatic response to environmental stressors, generating a reaction in the endocrine system that leads to physiological and behavioural responses (Collier et al. 2019). Below, these responses will be reviewed in more detail.

2.2.1. Physiological response

When the cow's surface temperature equals the ambient temperature, the temperature gradient disappears and the only way to lose heat is through evaporation by panting and sweating (Collier & Gebremedhin 2015). An increased respiration rate, i.e. panting, is one of the early indicators of heat stress and disposes heat through both convection and evaporation (Silanikove 2000). During panting, heat is removed through vaporized moisture from the lungs heated up by the body core (Collier & Gebremedhin 2015). Increasing respiration rate is an effective way to cool down the blood passing the nasal area on its way to the brain, enabling the brain to keep a lower temperature than the core body (Silanikove 2000). A study by Brown-Brandl et al. (2005) concluded that respiration rate was impacted at lower temperature compared to other responses, meaning it is the earliest sign that the environment no longer within the TNZ for the cow.

The most effective responses are heat loss through skin surface by sweating (Blazquez et al. 1994). According to a study evaporation through sweating accounts for 85% of the total heat loss when the temperature is greater than 30°C (Maia et al. 2005). However, the side- effects of sweating is that it will deplete the body-water reserves (Collier & Gebremedhin 2015) and the cooling effect will decrease as the relative humidity increase, making it less effective in environments with high humidity (Kimmel; et al. 1991).

2.2.2. Behavioural response

Various of behavioural responses to heat stress are applied by the cow, such as seeking shade and a changed lying behaviour (Armstrong 1994). While standing increases the available surface for evaporation and convection to the air, lying increases the available surface for conduction to the ground. Since the main response for a cow is evaporation, the cow reduces lying time when ambient temperature rises (Becker et al. 2020). The level of heat stress correspondent with the change, frequency, duration and position of lying pattern (Anderson et al. 2013).

Since the metabolism generates a lot of heat in the cow, an immediate response to decrease this heat production is reducing the feed intake (National Research Council 1981). The decline of feed intake begins at an ambient temperature of 25-26°C and more rapidly above 30°C (Baumgard & Rhoads 2013). Heat stress affects hypothalamus resulting in inhibition of the lateral appetite centre, which consequently leads to reduced feed intake (Kadzere et al. 2002). The loss of appetite may lead to a decreased dry matter intake of 9.6%, compared to what is eaten in the TNZ (Bouraoui et al. 2002). However, according to (National Research Council 1981), decreases in dry matter intake up to 55% during heat stress have been reported.

Another behavioural change is the water consumption. A high producing cow already has an increased water intake and consume even more during heat stress, meaning there is a positive correlation between water intake and the ambient temperature. However, when the ambient temperature exceeds 35°C, water intake may decrease since the cow becomes inactive (National Research Council (U.S.). Subcommittee on Dairy Cattle Nutrition. 2001). The main use of water during heat stress is for the evaporative cooling by sweating. However, a higher water intake also relates to an increase in total body water, and due to the high specific heat of water, it allows the cow to absorb a lot of heat during the day. Thereafter, the heat dissipates during the cool night through conductive cooling (Kadzere et al 2002). Since higher water consumption reduce internal temperature, a higher water consumption can significantly decrease the cow's respiration rate (Lanham et al. 1986).

2.3. Temperature-humidity index

The concept of Temperature Humidity Index (THI) was developed in 1958, and (Berry et al. 1964) extended its use to cattle. Since THI excludes solar radiation and wind speed, it is widely used for cows in modern intensive management systems providing shade (Tao et al. 2020). THI represent the combined effects of ambient temperature and humidity in relation to the cow's level of thermal stress, and a figure showing this can be found in the article by Armstrong (1994). To summarise, signs of mild heat stress become evident in dairy cows when THI exceeds 72, while severe heat stress arise when THI reach 78. Furthermore, when THI reach 89 the cow is in a state of very severe heat stress and when THI reach 98, the cows die due to heat stress (Armstrong 1994). Since cows are highly dependent on evaporative heat loss, a relatively low ambient temperature (22.8°C) combined with high humidity (85%) can cause mild heat stress. On the contrary, if the relative humidity is low (20%), the ambient temperature can reach 28.3°C before the cow enter a state of mild heat stress.

Since THI levels were developed a long time ago using cows producing 15kg milk/day, compared to today's high-producing cows with 30-40 kg/day, Zimbelman et al. (2009) argues that based on physiological and production parameters, THI threshold for cows producing more than 35 kg/day should be 68. At a THI of 68, the high-producing cow is affected adversely, and cooling methods should be implemented earlier to prevent heat stress (Zimbelman et al. 2009). This shift is considered a result increased sensitivity to high ambient temperatures due to increased productivity, resulting in a greater internal heat load, in combination with the animal's genetical tolerance of thermal stressors being difficult to improve (Collier et al. 2019).

According to SMHI (2018), parts of Sweden reached THI of 78 during the summer 2018, which corresponds with severe heat stress for high producing dairy cows. Furthermore, the southern half of Sweden had at least 50 days of a THI above 68, while some parts reached up to 80 days in total.

2.3.1. Energy balance

A study in Georgia on 22 lactating Holstein cows showed that the physiological response of reducing feed intake begins at a THI over 72.1. This follows by a reduced feed intake of 0.5 kg per THI unit increased, which means that feed intake decreases gradually with the increasing heat stress (West et al. 2003). Furthermore, according to (National Research Council 1981) an effect of mild to severe heat stress is increased metabolic maintenance requirements by 7 to 25%. The combination of decreased feed intake and increased metabolic maintenance requirement makes it difficult for a high producing cow to meet their energy demand, which consequently result in a negative energy balance (Rhoads et al. 2009; Becker et al. 2020).

2.3.2. Milk production

It is widely known that dairy cows decrease their milk production during periods of heat stress (Kino et al. 2019). Mellado et al. (2011) found that cows entering lactation during the hotter season of the year had lower milk yield compared to the cows induced into lactation during the cooler seasons. Furthermore, Kino et al.

(2019) recorded over 4000 cows from 2012 to 2016 in a temperate climate area and presented that increased heat stress caused linear decrease in milk yield.

Even if there is an agreement that milk yield decreases when the THI increases, the amount of decrease per unit THI differ between studies. Furthermore, the interval of THI measured varies. In a study by West et al. (2003), the results showed a milk yield reduction of 0.88 kg/day per unit increase in THI from 72.1 to 83.6. However, Könyves et al. (2017) got a higher milk drop in their study with a daily reduction of 1.32 kg milk within a similar THI interval. Another example is the study by Zimbelman et al. (2009) that presented a daily milk yield reduction of 2.2 kg/day when the THI values increased from 65 to 73, which implies a linear reduction in milk yield of 0.13 kg/day per unit increase in THI from 60-80. Furthermore, Herbut & Angrecka (2012) conducted a study in Poland where the decrease in daily milk yield from 0.18 to 0.36 kg per THI unit increase. Only one study included the effects of pasture, investigating both indoor systems and pasture-based systems. The study was made in Germany by Brügemann et al. (2012), who found that milk yield declined by 0.08 kg per THI unit for regions with indoor systems and 0.17 kg per THI unit for grazing based systems. To the authors knowledge no similar studies have been done in Sweden. However, all studies mentioned above are comparable to the Swedish standard, since they are made on dairy herds in indoor systems and exclusively measures the environmental conditions using ambient temperature and the relative humidity (=THI).

Many factors regarding the lactation influences how much the milk production decreases during heat stress and studies confirm that the early stage of lactation is the most vulnerable (Tao et al. 2020). Novak et al. (2009) reported a greater decrease in milk production during early lactation than in mid or late lactation, meaning that at cows in early lactation were more sensitive to the effect of heat than cows in late lactation. According to Sharma et al. (1983) the increased metabolic heat, the first 60 day in milk and at peak lactation are critical for managing heat stress to minimize effects on milk production.

The main reason for milk production decreases associated with heat stress has been proposed to be the reduced dry matter intake (West 2003). However, Rhoads et al. (2009) demonstrated a study where cows exposed to normal temperature had their DMI adjusted to be equal to that of cows in heat stress, which showed that reduced feed intake only accounts for about 35% of the decreased milk production during heat stress. Another study by Wheelock et al. (2010), suggested that the feed intake accounts for about 50%. This means that the reduced milk production is due to both the reduced feed intake and the heat stress itself as its affect’s different endurance functions important for milk flow (Rhoads et al. 2009). Moreover, Wheelock et al. (2010) explain that a heat stressed cow have increased basal and stimulated insulin levels. Consequently, the normal glucose-sparing mechanisms that maximize milk yield during period of nutrient insufficiency cannot be engaged by a heat stressed cow.

Other factors influencing the decreased milk production during heat stress, is impaired mammary growth during the dry period, which leads to reduced milk production in the subsequent lactation. Furthermore, the authors also suggests that if a cow is exposed to heat stress during late gestation, their offspring is affected by a lower milk production during their first lactation (Tao et al. 2018). This result is confirmed by Laporta et al. (2020), with data from 10 years late-gestation heat stress studies showing that maternal heat stress during late gestation reduces the cow's daughter's survivability and milk production up to 3 lactations.

2.3.3. Health

During periods of heat stress, the immune cells functionality is supressed which makes the cow more susceptible to pathogens (Kadzere et al. 2002). The combination of more pathogens during the warm and humid summer month and the negative effects of heat stress on the cow's immune system, the cow's risk of diseases and infections increases greatly during summer months (Kadzere et al. 2002; Tao et al. 2020).

Somatic cell count (SCC) is used as an indicator of milk quality and a marker for intensity of mammary inflammatory response. SSC and mastitis are connected due to the main source of increase in somatic cells is white blood cells of polymorphonuclear neutrophil leukocytes, which is the main defence mechanism in the udder against bacteria's causing mastitis (Becker et al. 2020). Summer month are well-known to be correlated with an increase of mastitis cases and a higher SSC due to the increased pathogen load in the environment (Lievaart et al. 2007; Das et al. 2016; Tao et al. 2020). This implies that an increase in THI may result in an increased SCC and risk for mastitis due to what the high ambient temperature brings (Das et al. 2016).

2.3.4. Fertility

The relationship between heat stress and reduced fertility is widely acknowledged (Kadzere et al. 2002; Jordan 2003; de Vries & Risco 2005; Wolfenson & Roth 2019). A consistent decrease in reproductive efficiency during the summer months compared to the winter months has been measured from 1976 to 2005 in the United States (de Vries & Risco 2005). Also, an analysis of pregnancies in over 20 000 dairy cows indicated a decreased pregnancy rate of 1.03% per unit THI increased above 72 (Domínguez et al. 2005). Furthermore, in a study by Wolfenson et al. (1995) the development of follicles in heat stressed dairy cows was found to be affected and began to decline earlier compared to cows in thermoneutral environment.

As explained by de Rensis & Scaramuzzi (2003), the reduced feed intake followed by negative energy balance due to heat stress reduces plasma concentrations of insulin, glucose and IGF-I, which can all affect reproduction. Wolfenson & Roth (2019) explains that the reproductive tract and its processes are highly sensitive, and therefore becomes impaired and do not develop correctly when exposed to elevated temperatures. In addition, the lower chance of pregnancy during the summer month may also be explained by the difficulties with heat detection when the cows are on pasture (Löf et al. 2014).

2.4. Methods to reduce heat stress

Increases in productive of dairy cows compromise their ability of thermal acclimatization, meaning greater investments in housing systems to reduce the variability of the thermal environment is required (Collier & Gebremedhin 2015). Methods to reduce the effects of heat stress successfully involves modification of the housing system that maximize heat exchange through convection, conduction, radiation, and evaporation (Negrón-Pérez et al. 2019).

2.4.1. Housings and systems

According to their climatic conditions, loose housing systems can be characterized into two cold and warm housing systems. Schnier et al. (2003) characterized cold housing systems as uninsulated buildings with a microclimatic condition similar to the macroclimatic conditions outside, while warm housing systems have a constant microclimatic condition throughout the year due to the insulated roof and walls. Some cold housings may have either insulated roof or walls.

A study by Lambertz et al. (2014) compared the effects of THI on milk production in cold and warm loose housing systems. The warm loose-housing systems had a slightly higher monthly THI values, with the greatest difference between the systems during the winter months, which is explained by the insulation. Furthermore, the insulation of warm housings prevents rapid heating during the days, with the trade-off that cooling of the barn takes longer, in comparison with cold housings. This is especially relevant during hot summer days. However, in both cold and warm housing systems the cows were exposed to THI values above thermal comfort to the same extent, meaning the effects did not vary between the housing systems (Lambertz et al. 2014). This result is consistent with study by Schnier et al. (2003), which investigated the milk production as an indicator of thermal comfort and found no significant differences between the housing systems. The reason why performance between the systems do not differ is explained by Zähner et al. (2004), investigating the effects of the varying temperature in cold housing systems, influenced by the temperature outside. Basically, the extra heat the cows are exposed to during warm days in cold housing systems, induces a stronger thermoregulatory response in the cows during the much cooler night. This enables comparable production results between the cold housings and the warm housings.

A study by Liberati (2009) investigated the influence of the roof construction in both warm and cold housing systems. They found that the most relevant factor to reduce heat stress in cows is a well-insulated roof especially for warm housing systems. According to the study, the most relevant factor for cold housing systems on the other hand is the possibility for good wind action.

A study made in Norway investigated the possible associations between ventilation system and milk production in housings for dairy cows (Næss et al. 2011). The study investigated the difference between warm housings with controlled or mechanical ventilation and cold housings with natural ventilation. The results showed that milk production was significantly higher in warm housings with controlled natural ventilation and mechanical ventilation compared to cold housings with natural ventilation (Næss et al. 2011). Another study investigated the most effective way to cool dairy cows during warm periods, comparing mechanical ventilation system and the use of extra fans and misters (Dikmen et al. 2020). The results showed a lower rectal temperature in the systems with mechanical ventilation, but only when the barn was originally built with it, and not when the mechanical ventilation was a reconstruction of a system originated for fans and sprinklers. Furthermore, the study examined the seasonal reduction in milk production, whereas the decrease in mechanical ventilation system were 3.5% compared to 5.8% in the system with sprinklers and fans.

A comparative study was made by Speroni et al. (2006) to evaluate the difference in milk production during heat stress between an automatic milking system (AMS) and a conventional milking system. The reduction in milk yield was higher for the cows in the AMS compared to the conventional milking system. Also, the milking frequency decreased in the AMS when the cows were heat stressed, and therefore also the visits to the feeding area. In the AMS, the cows decreased activity due to heat stress led to a lower voluntary milking frequency, and therefore also lower feed intake. The author discussed that decreased milking frequency and feed intake may be reason for the reduced milk yield for the cows in the AMS.

2.4.2. Preventive measure: Extra fans and sprinklers/misters

Many studies have investigated the effects of evaporative and conductive cooling method in form of fans and misters/sprays to reduce heat stress in dairy cows, and the best effect seems to be when shade is combined with fans and sprinklers (Armstrong 1994; Correa-Calderon et al. 2004; Kendall et al. 2007; Calegari et al. 2016). Silanikove et al. (2009) justified this in a heat stress-study showing a 18% decrease in milk yield when cows had access to cooling by fans and sprinklers but no shade, whereas the reduction in milk yield for cows which had access to both shade and cooling by fans and sprinklers were 7.9%. The reason for the higher efficacy when shade and sprinklers is combined, is because the shade cools down the cow faster, while sprinklers ensure that the cow remains cool for a longer time (Kendall et al. 2007).

During the study by Correa-Calderon et al. (2004) THI span from 73 to 85, results showed a higher rectal temperature and respiration rate in a group of dairy cows with only access to shade, compared to a group with access to both shade, fans and sprinklers. However, in a similar study investigating the effect of extra fans and misters, the rectal temperature remained below 39 in both groups when mild to moderate heat waves was observed (Calegari et al. (2016). On the other hand, the group with fans and misters maintained milk yield better, had a lower breathing rate and spent more time lying down compared to the group with access to shade alone (Calegari et al. 2016). The results from these two studies agree with the conclusion of Kendall et al. (2007), stating that shade in combination with sprinklers can reduce the respiration rate markedly and improve welfare compared to only providing shade.

Studies have also investigated the effect of increased use of sprinklers/misters in combination with fans, which have shown to increase the positive effects (Calegari et al. 2012; Kleinjan-Elazary et al. 2020). The results by Calegari et al. (2012) suggested cooling systems using fans and a higher frequency of misters are to prefer, since it improved comfort by greater resting time and lower breathing rate. Another study compared the effects of increasing number of cooling sessions to 8 instead of 5, which also indicated a higher welfare in form of more lying time and better activity (Kleinjan-Elazary et al. 2020).

Despite cooling using sprinklers/misters being an effective evaporative technology, concerns arise regarding the large volume of water needed and the amount of wastewater this system infer. Even without sprinklers or mists, a lower water usage and contamination are critical to the sustainability for the dairy industry (Chen et al. 2015).

2.4.3. Preventive measure: Pasture management

THI has shown to be lower in shaded areas compared to areas with no shade (Kendall et al. 2007). Therefore, providing shade for dairy cows on pasture can significantly reduce their respiratory rates and rectal temperature (Veissier et al. 2018). On pasture, trees are the most effective shade producers since they combine the effect of protection against the solar radiation and the leaves evaporative moisture which have a cooling effect. However, if tree is not an option, the most cost-effective and low maintenance shade material is sheet steel (Armstrong 1994). Furthermore, Collier et al. (2006) reviewed the impact of shade and suggested that the shade area should provide 3.5-4.5 m2/cow and be 4.3 m high to reduce the udder injury and intensity of solar radiation. It is recommended that the orientation of the shaded area is taken into consideration to allow sunlight dispersion beneath the shade (Armstrong 1994). However, according to a study by Tucker et al. (2008), the proportion of solar radiation the shade is blocking had small effect on the cow's body temperature, since no shade and shade blocking 25%, 50% and 99% of the solar radiation only resulted in body temperature difference of 0.2 C. Although it was clear that the cows preferred the shade that provided 99% compared to the 25% protection of solar radiation.

Northern latitude within temperate climate has pleasant, short and light summer nights, which makes it well suited for night-grazing systems. In a study by Charlton et al (2013) found that the cows had a higher motivation to visit the pasture during night compared to during the day. Pasture during the night was more important for the cow, improved the comfort and welfare and maintain the production (Charlton et al. 2013). In a recent study by Kismul et al. (2019), in which cows had access to 12 hours pasture during the night, cows showed a higher motivation to use the pasture during the early evening and then spend time inside during the remaining night, even if the outside was cooler during the night. An explanation for why cows did not use the pasture during the night to cool the body temperature may be that THI never reached the threshold of 72 during this study. Thus, cows did not experience heat stress inside nor outside.

3. Material and method

3.1. Study design and study population

Selection of farms for the interviews was based on information from the Swedish milk and disease recording system (SMDRS). Data on milk production, fertility and somatic cell counts from 2016-2019 from all Swedish dairy herds with more than 50 cows that participates in the SMDRS were acquired. A list of 200 farms, including 100 farms that were more affected by summer periods associated with a greater rise in somatic cell counts or reduced fertility (cases) and 100 farms that were not affected by the summer season (controls). The farmers on the list were contacted by local advisors and veterinarians at Växa Sverige AB and asked to participate in the project until 30 farmers willing to participate had been identified, see figure for the farms geographic position (Fig 3). The farmers were contacted by the author to schedule a time for the interview and the interview was performed over phone. The interviews were conducted during February, Mars and April. An interview survey took on average 45 minutes to complete and the answers were summarized into an excel sheet. The survey included questions focused on the farmers experience of extreme weather and the consequences, housing design and routines for milking, feeding and reproduction (Appendix).

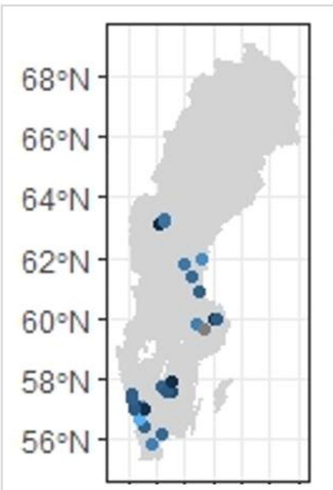

Figure 3. The geographic position of the 30 farms included in the study.

3.2. Processing of qualitative data

The 30 interviews relevant herd characteristics were processed in an excel sheet into categories. Each category was then divided into parameters based on the possible options (Table 1). These categories were made to enable investigation and implementation of statistical tests.

Table 1. The first column, Category show herd characteristics and the distinct system/measure for each category are identified in the second column, called Parameter. The parameters implication and requirements are explained in the Description column

Category	Parameter	Description
Year of construction	Before 2000	Housings built before year 2000
	After 2000	Housings built on and after year 2000
Housing	Warm	Housings with insulated roof and walls. Have a constant climatic condition throughout the year
	Cold	Housings without insulated roof and walls. Have a microclimatic condition like the macroclimatic conditions outside
Ventilation	Natural	Air flows through housings non-insulated open side walls (only cold housings)
	Controlled	Air flow controlled by openable roof ridge and wall panels (both warm and cold housings)
	Mechanical	Air flow controlled by fans (only warm housings)
Milking system	AMS	Automatic milking system
	Conventional	Conventional milking system (herringbone/side-by-side).
Preventive measure	Applying preventive measure	Farmer apply preventive measures to cool the dairy herd down when cows show signs of heat stress
	Fans	Extra fans installed before summer 2018, used when cows show signs of heat stress.
	Shower	Shower cows in water with a hose when they show signs of heat stress
	Pasture	Change pasture to one with more shade or change the time of day the cows are on the pasture when they show signs of heat stress
	No preventive	Farmer do not apply preventive actions to heat stressed cows
Experiences cows as warm	Experience	Farmers experiences the cows as warm during the summer
	Do not experience	Farmers do not experience the cows as warm during the summer
Signs of warm cow	Behaviour	Farmer describe a changed behaviour (eating/laying/activity) as a sign of warm cows
	Panting	Farmer describe panting as a sign of warm cows
	Behaviour & Panting	Farmer describe both panting and changed behaviour as a sign of warm cows

3.3. Processing of quantitative data

The information of the farms performance was gathered from the Swedish milk recording system. Information from monthly trial-milking's were presented as Energy corrected milk (ECM) and compared using proportional difference, showing the milk drop between two periods in percent. These periods were summarised in two different approaches, see below.

- *Proportional difference in average ECM between November 2017-June 2018 and July-August 2018.*

The first approach was used to show how much the hot period of summer of 2018 affected a farm compared to a seven-month period before. This was made by comparing the hot summer months (July-August 2018) average ECM with the milk production the period before (November 2017 to June 2018).

- *Proportional difference of average ECM between July-August 2017 and July-August 2018.*

The other approach was made to show how much the summer of 2018 affected the farm compared to a normal summer. Therefore, it was presented using the proportional difference between the average ECM in kg during July and August 2018 in comparison to same month during 2017.

3.4. Statistical analysis

Statistical analyses to test and investigate the factors affecting the milk production were done in Minitab using Mann-Whitney test. This test determines whether the population median of two groups differ and calculate a range of values that is likely to include the difference between the population medians. The null-hypothesis was applied, assuming that there was no difference between the two treatments, and a p-value of <0.05 was considered statistically significant.

All categories presented in Fig. 1 were investigated univariably and some were also combined to further investigate the interaction between factors. For the first hypothesis, the factors Year of construction, Housing, Ventilation and Milking system were examined. To investigate the interaction between these three factors, the most frequent system-combination: Modern warm housing with controlled ventilation were compared to the rest of the systems. For the second hypothesis, the factors Applying preventive measures, Fans, Shower and Pasture management were tested. To investigate the third hypothesis, the interaction was tested between the factors Experiences cows as warm and Preventive measures.

Boxplots were made to further investigate the parameters differences and visualize the difference in the proportional milk production reduction. Boxplots shows the median, interquartile range, and outliners for each parameter.

4. Results

4.1. Farm characterization

Among the 30 farms that were interviewed for this thesis, the average herd size was 108 milking dairy cows, and the median was 95 milking dairy cows. Half of the farms had between 50-99 milking dairy cows, 12 farms had 100-149 and three farms had 200 or above. Half of the farms had AMS, and half had conventional milking system.

Most farms, 22 of them, had warm housings for the dairy cows, while 8 of them had cold housings. All farms except for two of the warm housings were loose housing systems, meaning the cows move around freely in the barn. As shown in the figure below, the most frequent combination of system was warm housing built after year 2000 with controlled ventilation. This system was used on10 of the 30 farms (Fig 4). The second most common system, which 9 farms had were warm housing built before 2000 with mechanical ventilation. Half of the 8 cold housing systems were built before year 2000 and the other half after year 2000. All the cold housings had natural ventilation, except one with controlled ventilation.

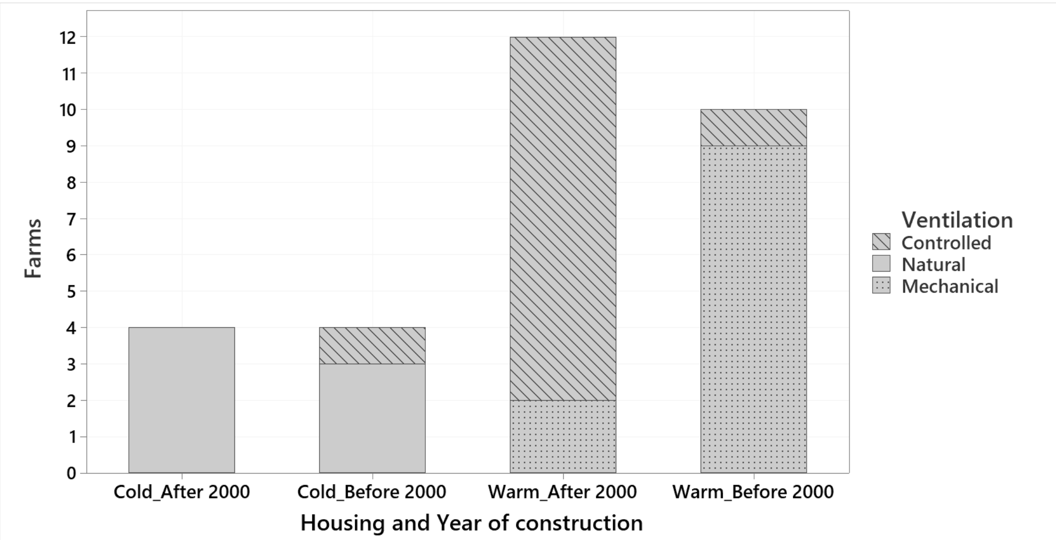

Figure 4. The distribution of housing (cold or warm), year of construction (before or after year 2000) and ventilation (controlled, natural or mechanical) among the 30 farms.

The summer of 2018 had varied effect on the 30 farms. The milk production dropped with an average of 10.5% during the July and August 2018 compared to a period before (November 2017-June 2018). The median of milk production drop between these periods were 8.33%, and 10 of the farms had a milk drop between 5-10%, which can be seen in the figure (Fig 5). The figure also shows that two of the farms had an increase in milk production during the summer 2018, while two other farms got heavily affected with a milk drop of 30-35%.

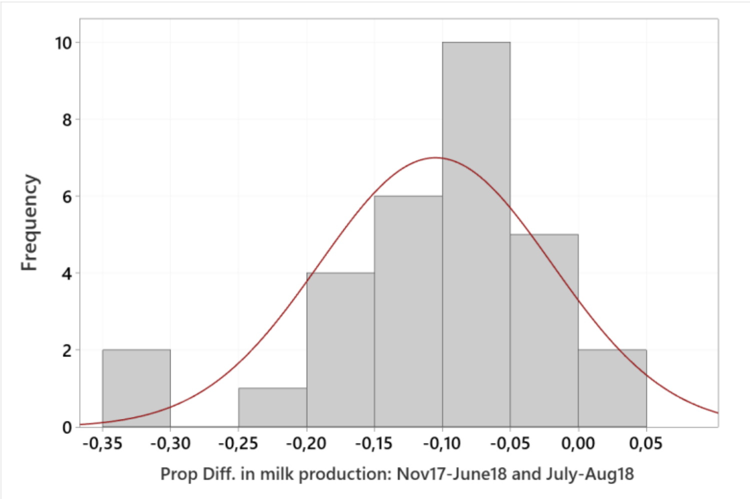

Figure 5. Histogram showing the proportional difference in milk production between November 2017 to June 2018 and July to August 2018 among the 30 farms.

When comparing the milk production during the 2018 with the previous summer (2017), the average drop in milk production were 3.5% and the median was 3.75% (Fig 6). When comparing the summer 2017 and 2018, there was 11 farms that had an increase in milk production during 2018 (up to 20%). The farm with the largest drop had 20-25% lower milk production during summer 2018 compared to the summer of 2017.

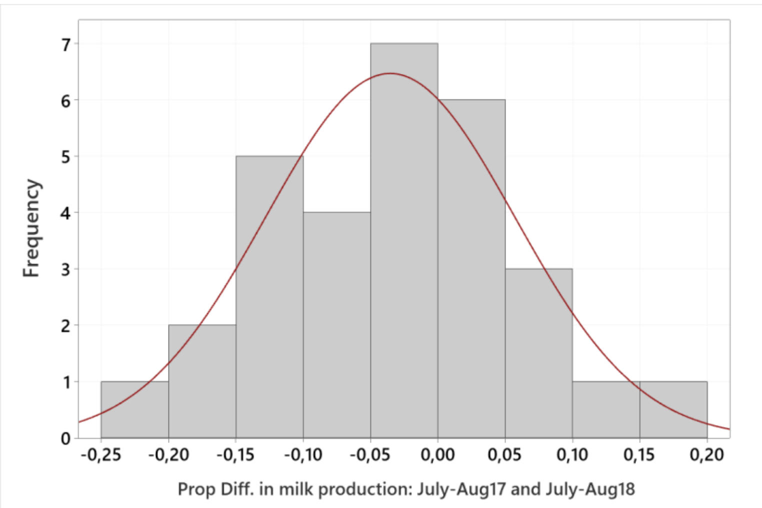

Figure 6. Histogram showing the proportional difference in milk production between July to August 2017 and July to August 2018 among the 30 farms.

4.2. Housing and system

The results from Mann-Whitney test regarding housing and system, comparing the hot summer month 2018, July-August with both a period before, November 2017-June 2018 and the summer before, July-August 2017 (Table 2).

Table 2. Mann-Whitney test results for housing and system-related factors, comparing the period July-August 2018 with both November 2017-June 2018 and July-August 2017, including the p-value, significance (ns=No significance, sig.= 5% significance level), number of farms with each parameter (N) and the parameters median and mean

November 2017-June 2018 and July-August 2018						
Factor	**P-value**	**Sig.**	**Parameter**	**N**	**Median**	**Mean**
Year of construction	0.662	ns	Before 2000	14	-0.0949	-0.1170
			After 2000	16	-0.0833	-0.0946
Housing	0.412	ns	Warm	22	-0.0878	-0.1068
			Cold	8	-0.0665	-0.1002
Most frequent system	0.843	ns	Modern warm housing with controlled ventilation[1]	10	-0.0833	-0.0914
			Other system-combinations[2]	20	-0.0949	-0.1119
Milking system	0.619	ns	AMS	15	-0.1091	-0.1095
			Conventional	15	-0.0808	-0.1006
July-August 2017 and July-August 2018						
Factor	**P-value**	**Sig.**	**Parameter**	**N**	**Median**	**Mean**
Year of construction	0.519	ns	Before 2000	14	-0.0400	-0.0461
			After 2000	16	-0.0371	-0.0261
Housing	0.106	ns	Warm	22	-0.0261	-0.0185
			Cold	8	-0.0567	-0.0818
Most frequent system	0.045	sig.	Modern warm housing with controlled ventilation[1]	10	0.0109	0.0151
			Other system-combinations[2]	20	-0.0465	-0.0607
Milking system	0.135	ns	AMS	15	0.0023	-0.0108
			Conventional	15	-0.0484	-0.0600

[1] Farms with warm housings and controlled ventilation built after year 2000.

[2] Farms with other system-combinations: Cold housings with controlled or natural ventilation, warm housings with mechanical ventilation and warm housings with controlled ventilation built before year 2000.

4.2.1. Year of construction

When comparing the milk production during the hot summer month of 2018 with the 7-month period before, the year of construction was shown to have relatively small effect. Although, a slightly higher performance for the farms with housings built after year 2000, with an average milk production drop of 9.5% compared to the farms with older housings with 11.7% milk production drop in average.

Comparing the hot summer month 2018 with the same months in 2017, the modern housings had an average milk drop of 2.6% and the older building, 4.6%. The Box plot shows how small the effect housing had on milk production considering that the median for the housings built after 2000 and housings built before 2000 does not differ much (3.7% and 4%) (Fig 7). However, the inter-quartile range showing the distribution of difference among farms shows that several farms with housings built after 2000 had an advantage (increase in milk production) while most farms with houses built before 2000 had a comparable or lower production.

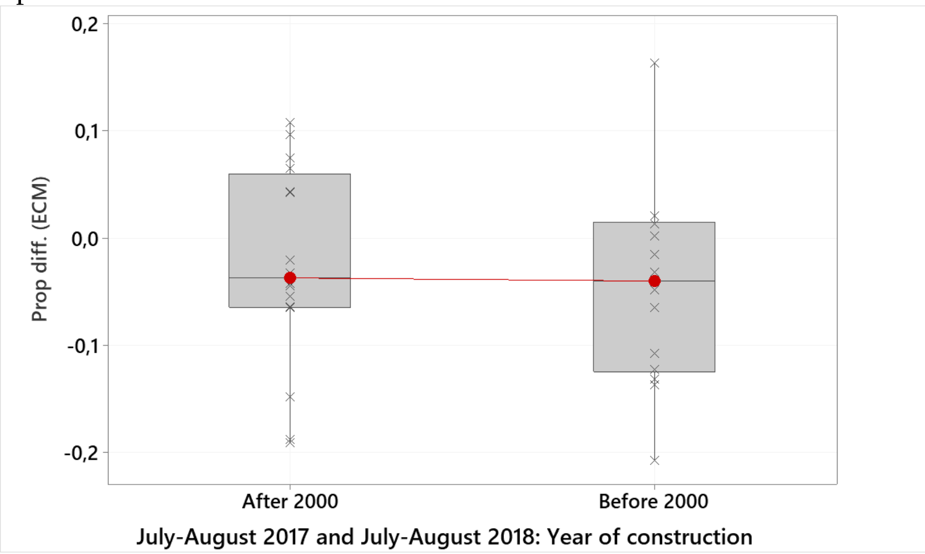

Figure 7. Boxplot of the factor: Year of construction, showing the proportional difference in ECM between the two parameters (After year 2000 and Before year 2000). Showing inter-quartile range containing 50% of the values, whiskers containing 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

4.2.2. Housing

Type of housing did not have a clear impact on the milk production when comparing the summer 2018 with the period before (nov17-jun18) and the average milk drop was similar (~10%) in both housing systems.

However, when comparing the hot summer months 2018 and the same months 2017, type of housing was associated with a difference in milk production ($p=0.106$), with an advantage for warm housings. Farms with warm housings performed better with an average ECM drop of 1.85% compared to the cold housings with 8.18% ECM drop. However, the box plot shows a greater spread in the effect on ECM for the warm housings, from nearly 20% drop to more than 15% increase (Fig.8). Thus, there was a large variation in performance within this group. Among farms with cold housing systems, only one farm had an increased ECM and one affected comparable ECM to previous year (0%). The remaining 6 farms with cold housing systems had a drop in ECM and the largest drop reaches over 20%.

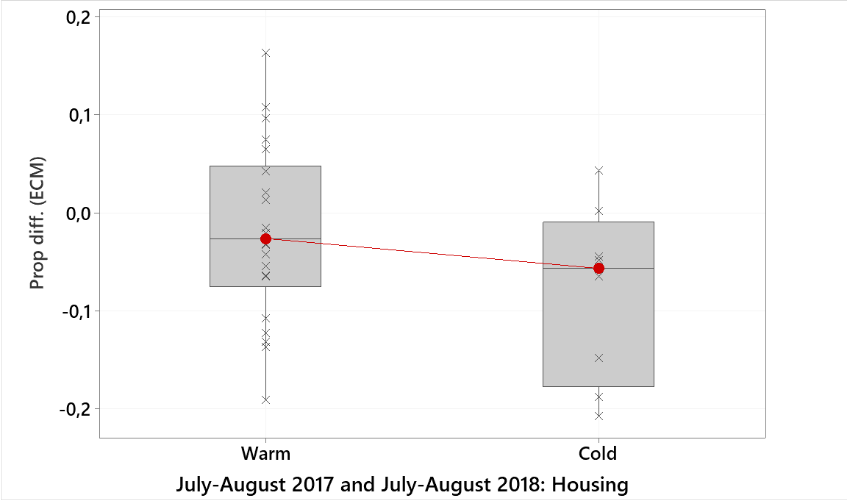

Figure 8. Boxplot of the factor: Housing, showing the proportional difference in ECM between the two parameters (Warm and Cold). Inter-quartile range with 50% of the values, whiskers with 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

4.2.3. Ventilation

A box plot was made to examine the effect of different ventilation systems, comparing the hot month of 2018 and the same month 2017 (Fig 9). The Box plot showed that the different ventilation systems had similar decreases in ECM, with a median of 3.1% for mechanical, 3.2% for controlled and 4.8 for natural. A possible advantage for farms with controlled ventilation can be seen in the spread of observations as several of these some farms showed an increased ECM during 2018. For the other groups there were few farms that increased production and more farms with almost no difference in proportional difference for ECM between the mechanical and natural ventilations systems.

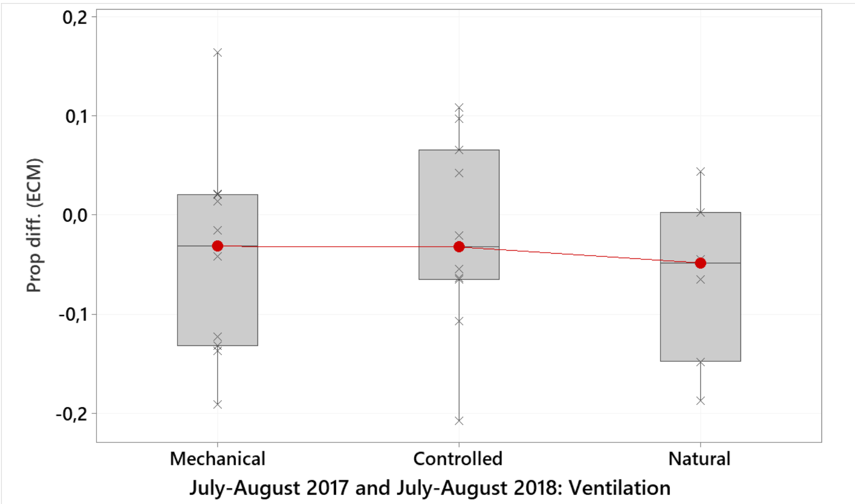

Figure 9. Boxplot of the factor: Ventilation, showing the proportional difference in ECM between the three parameters (Mechanical, Controlled and Natural). Inter-quartile range with 50% of the values, whiskers with 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

4.2.4. The most frequent system: Modern warm housing with controlled ventilation

The most frequent system, that 10 of the farms had, was the modern warm housing with controlled ventilation, while the rest was either cold housings or warm housings with mechanical ventilation and one exception of warm housing with controlled ventilation built before 2000. When examining the summer 2018 compared to the seven-month period before, there was no significant difference on performance between systems. Thus, farms in both groups were similarly impacted by the summer season.

The modern warm housing with controlled ventilation had a positive impact on milk production with a statically significance (p = 0.045), when comparing the hot summer month 2018 with the same month 2017, which can be seen in the box plot (Fig 10). This indicates that the farms with the most frequent system did not experience added negative effects due to the extreme heat during summer 2018 to the same degree as the other farms. During summer 2018, the most common systems had on average increased ECM of 1.5% compared to a decrease of 6% for the other systems. The median for the most common system were 1% increased ECM during the hot summer month 2018, while the median was a decrease of 4% ECM for the other systems.

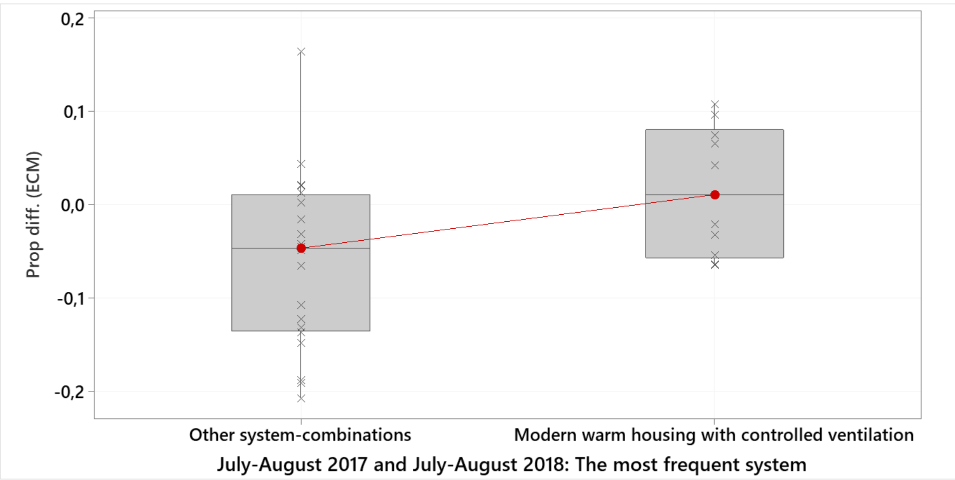

Figure 10. Boxplot of the factor: The most frequent system, showing the proportional difference in ECM between the two parameters (Modern warm housing with controlled ventilation and Other system-combinations which includes: cold housings with controlled or natural ventilation, warm housings with mechanical ventilation and warm housings with controlled ventilation built before year 2000). Inter-quartile range with 50% of the values, whiskers with 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

4.2.5. Milking system

There was no difference in the impact of summer on milk production on farms with different type of milking system when comparing the hot summer month 2018 with the seven-month period before. Both farms with AMS and conventional milking system had an average drop in ECM of 10%. However, the median was nearly 11% decrease in ECM for AMS, while the median was as 8% for the conventional systems.

The two milking systems were associated with a difference (p=0.135) when comparing the hot summer months 2018 with the same months 2017. Farms with AMS had an average ECM drop of 1% during the summer 2018, while the farms with conventional milking system had an average drop of 6%. More than half of the farms with AMS had an increased ECM during 2018, with a median of +0.2%, while the farms with conventional milking systems had a decrease in ECM, with a median of -4.8% (Fig 11).

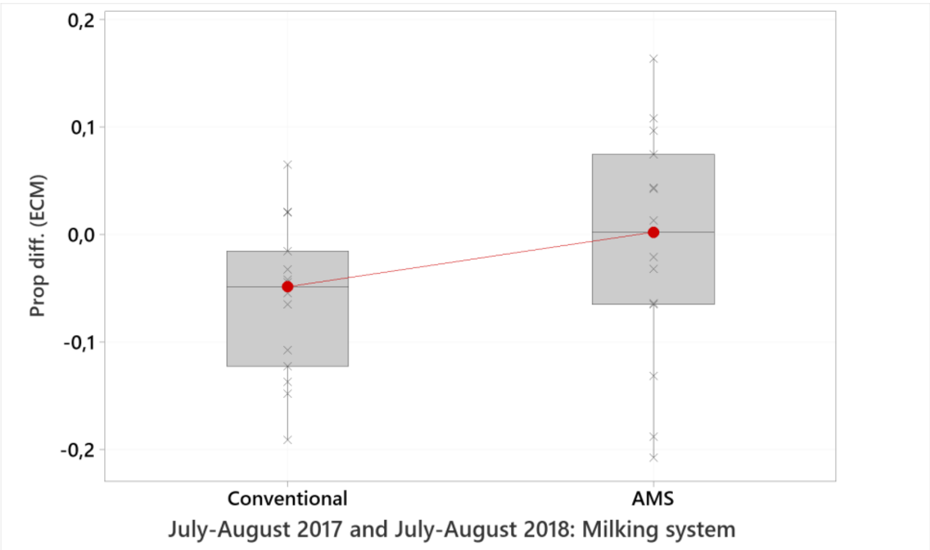

Figure 11. Boxplot of the factor: Milking system, showing the proportional difference in ECM between the two parameters (Conventional and AMS). Inter-quartile range with 50% of the values, whiskers with 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

4.3. Preventive measures

The results from Mann-Whitney test regarding preventive measures, comparing the hot summer months, July - August 2018, with both a period before, November 2017-June 2018 and the same months a year before, July-August 2017 (Table 3).

Table 3. Mann-Whitney test results for preventive measure-related factors, comparing the hot summer period July-August 2018 with both November 2017-June 2018 and July-August 2017, including the p-value, significance (ns=No significance, sig.= 5% significance level), number of farms with each parameter (N) and the parameters median and mean

November 2017-June 2018 and July-August 2018						
Factor	**P-value**	**Sig.**	**Parameter**	**N**	**Median**	**Mean**
Applying preventive measure	0.709	ns	Preventive measure	15	-0.0776	-0.1003
			No preventive	15	-0.0912	-0.1098
- Fans	0.951	ns	Fans	5	-0.0776	-0.0801
			Shower + Pasture[1]	10	-0.0746	-0.1104
- Shower	0.954	ns	Shower	7	-0.0595	-0.1200
			Fans + Pasture[2]	8	-0.0799	-0.0830
- Pasture management	0.648	ns	Pasture	4	-0.0746	-0.0633
			Fans and Shower[3]	11	-0.0776	-0.1137
July-August 2017 and July-August 2018						
Factor	**P-value**	**Sig.**	**Parameter**	**N**	**Median**	**Mean**
Applying preventive measure	0.619	ns	Preventive measure	15	-0.0446	-0.0421
			No preventive	15	-0.0323	-0.0287
- Fans	0.058	ns	Fans	5	0.0425	0.0413
			Shower + Pasture[1]	10	-0.0808	-0.0838
- Shower	0.325	ns	Shower	7	-0.0542	-0.0798
			Fans + Pasture[2]	8	-0.0261	-0.0092
- Pasture management	0.948	ns	Pasture	4	-0.0716	-0.0458
			Fans + Shower[3]	11	-0.0446	-0.0408

[1] Parameter includes both farms with showers and farms with pasture management.
[2] Parameter includes both farms with fans and farms with pasture management.
[3] Parameter includes both farms with fans and farms with showers.

4.3.1. Applying preventive measure

The Mann-Whitney test results implies that applying preventive actions when cows were warm did not have a significant effect on the milk production. Comparing the hot summer month 2018 with the seven-month period before, farms that applied preventive measures showed to be less affected by the heat with slightly better median and mean compared to the farms that did not apply any preventive measures.

When comparing the summer 2018 with the summer 2017, the farms that did not implement any preventive measures had an average ECM drop of 2.87%, while the farms that did implement preventive measures had an average of 4.21% milk production drop. The median decrease in milk production of the farms with no preventive measure was 3.2% and while the median for the farms that undertook preventive measure was 4.5% (Fig 12).

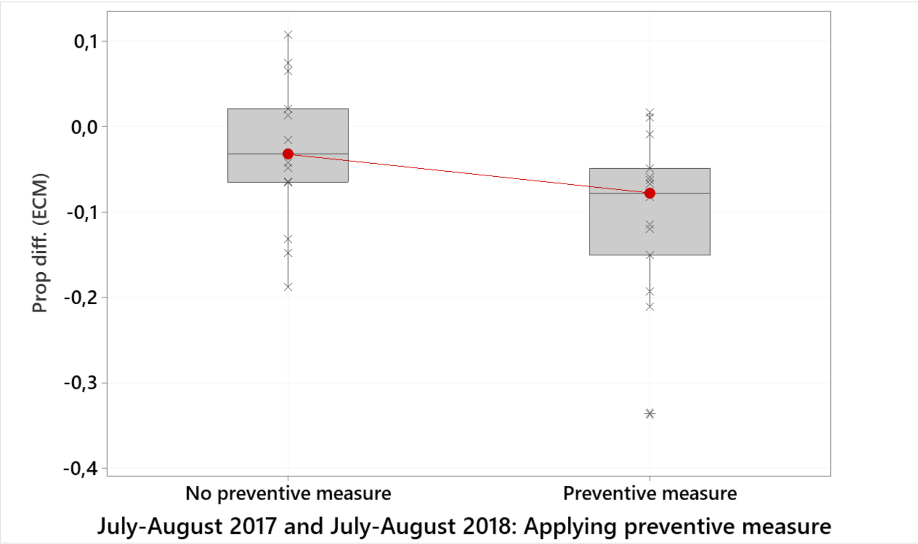

Figure 12. Boxplot of the factor: Applying preventive measure, showing the proportional difference in ECM between the two parameters (No preventive measure and Preventive measure). Inter-quartile range with 50% of the values, whiskers with 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

4.3.2. Type of preventive measure

The Mann-Whitney test results implied that the type of preventive measure did not have an impact on milk production. Comparing the hot summer month with the seven-month period before, the decrease in ECM was relatively similar regardless of preventive measures, with a median on 7.8% for fans, 6.0% for shower, and 7.5% for pasture management. Even if the median for shower meant least decrease, the average decrease for Shower were the greatest with 12%, while the average for the fans and pasture management together were on average 8.3%. One farm implemented both pasture management and the use of extra fans and were therefore included in both comparisons, which is why the sum of the parameter's fans, shower and pasture management is 16 instead of 15.

ECM during hot summer month 2018 compared the same month 2017 showed that the 5 farms with fans had an average 4.1% increase, while the farms applying shower or pasture management had an average decrease of 8.4%. Furthermore, more than half of the farms with fans had an increase in milk production, with a median of 4.25%, which can be seen in the box plot (Fig 13). Also, more farms applying shower had a lower decrease in milk production with a median of 5.4%, compared to the farms applying pasture management (7.2%). However, one farm with pasture management had an increase in milk production during 2018, making the average milk drop only 4.6% for the group, while two farms using showering were greatly affected making the average milk drop for shower 8.0%.

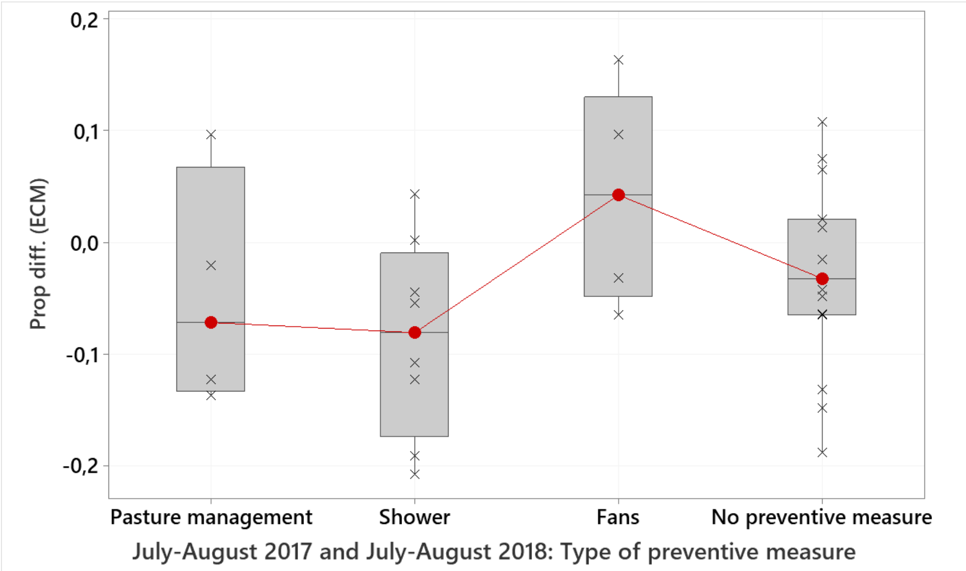

Figure 13. Boxplot of the factors: Fans, Shower and Pasture management, showing the proportional difference in ECM between the four parameters (Pasture management, Shower, Fans and No preventive measure). Inter-quartile range with 50% of the values, whiskers with 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

4.4. Experiences and actions

The results from Mann-Whitney test regarding experiences of warm cows, comparing the hot summer month 2018, July-August with both a period before, November 2017-June 2018 and the same month a year before, July-August 2017 (Table 4).

Table 4. Mann-Whitney test results for experience and actions, comparing the hot summer period July-August 2018 with both November 2017-June 2018 and July-August 2017, including the p-value, significance (ns=No significance, sig.= 5% significance level), number of farms with each parameter (N) and the parameters median and mean

November 2017-June 2018 and July-August 2018						
Factor	**P-value**	**Sig.**	**Parameter**	**N**	**Median**	**Mean**
Experiences cows as warm	0.786	ns	Experience	21	-0.0843	-0.1053
			Do not experience	9	-0.0808	-0.1045
- Experience & preventive measure	0.456	ns	Experience_Prev[1]	12	-0.0983	-0.1175
			Experience_No prev[2]	9	-0.0843	-0.0890
- Don't experience & preventive measure	0.093	ns	Do not exp_Prev[3]	3	-0.0487	-0.0316
			Do not exp_No prev[4]	6	-0.1184	-0.1410
Sign of warm cow: Panting	0.961	ns	Panting	7	-0.0822	-0.0911
			No panting	23	-0.0843	-0.1093
Sign of warm cow: Behaviour	0.129	ns	Behaviour	16	-0.0703	-0.0868
			No behaviour	14	-0.1230	-0.1259
Sign of warm cow: Panting & behaviour	0.062	ns	Panting & behaviour[5]	7	-0.1506	-0.1607
			No Panting & behaviour	23	-0.080	-0.0881
July-August 2017 and July-August 2018						
Factor	**P-value**	**Sig.**	**Parameter**	**N**	**Median**	**Mean**
Experiences cows as warm	0.222	ns	Experience	21	-0.0484	-0.0437
			Do not experience	9	-0.0205	-0.0162
- Experience & preventive measure	0.303	ns	Experience_Prev[1]	12	-0.0596	-0.0600
			Experience_No prev[2]	9	-0.0420	-0.0218
- Don't experience & preventive measure	0.366	ns	Do not exp_Prev[3]	3	0.0425	0.0295
			Do not exp_No prev[4]	6	0.0026	-0.0391
Signs of warm cow: Panting	0.007	sig.	Panting	7	0.0653	0.0496
			No panting	23	-0.0613	-0.0613
Signs of warm cow: Behaviour	0.329	ns	Behaviour	16	-0.0465	-0.0495
			No behaviour	14	-0.0261	-0.0193
Signs of warm cow: Panting & behaviour	0.128	ns	Panting & behaviour[5]	7	-0.1225	-0.0883
			No Panting & behaviour	23	-0.0206	-0.0193

[1] Farmers that did experience cows as warm and applied preventive measures.
[2] Farmers that did experience cows as warm and did not apply any preventive measures.
[3] Farmers that did not experience cows as warm and applied preventive measures.
[4] Farmers that did not experience cows as warm and did not apply any preventive measures.
[5] Farmers that described both panting and changed behaviour as a sign of warm cows.

4.4.1. Experiences and acting preventive

Comparing the milk drop during the hot summer months of 2018 with the seven-month period before showed no difference between farms where farmers experienced their cows as warm during the summer. The two parameters (Experience and Do not experience) had similar median (8-8.5%) and mean (10.5%) drops. However, when comparing the hot summer months 2018 with the same months 2017, the median for farmers that did not experience their cows as warm was a 2% increase in milk production, compared to a median of 4.8% decrease in milk production for the farmers that did experience the cows as warm (Fig 14).

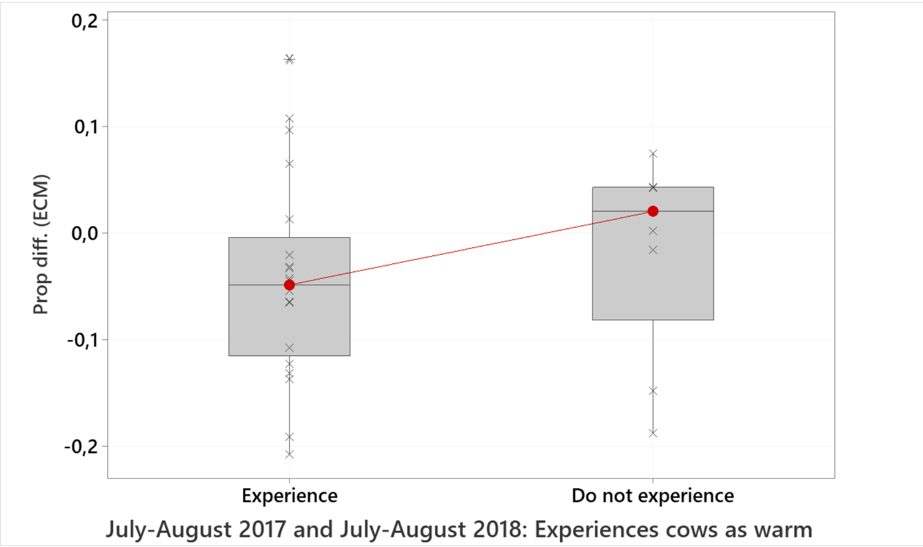

Figure 14. Boxplot of the factor: Experiences cows as warm, showing the proportional difference in ECM between the two parameters (Experience and Do not experience). Inter-quartile range with 50% of the values, whiskers with 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

A stratified analysis looking into the effect of preventive measures on farms where farmers experienced their animals as warm and farmers not experiencing their animals as warm was also made. Among farmers that did experience their cows as warm during summer performing preventive measures had no significant impact on milk production for either approaches of comparisons with the summer 2018. However, looking at the boxplot of for the comparison for the hot summer month 2018 with the same month 2017, only a slightly smaller decrease in milk production for the farmers that did not apply any preventive measures when they experienced the cows as warm can be seen (Fig15). Moreover, there is a great spread for the farmers that did apply preventive measures when the cows showed signs of heat stress, including both farms with nearly 20% increase in milk production and farms with over 20% decreased milk production.

Among the farmers that did not experience their cows as warm during the summers, three of them did apply preventive measure, while six of them did not apply any preventive measures. No significance difference could be detected for either approaches of comparisons with the summer 2018. Looking at the boxplot, the three farmers that did not experienced cows as warm but still applied preventive measures had a median on 4.3% increased milk production and were least affected by the summer heat, while there was a great spread in performance among the farmers that did not apply any preventive measures (Fig 15).

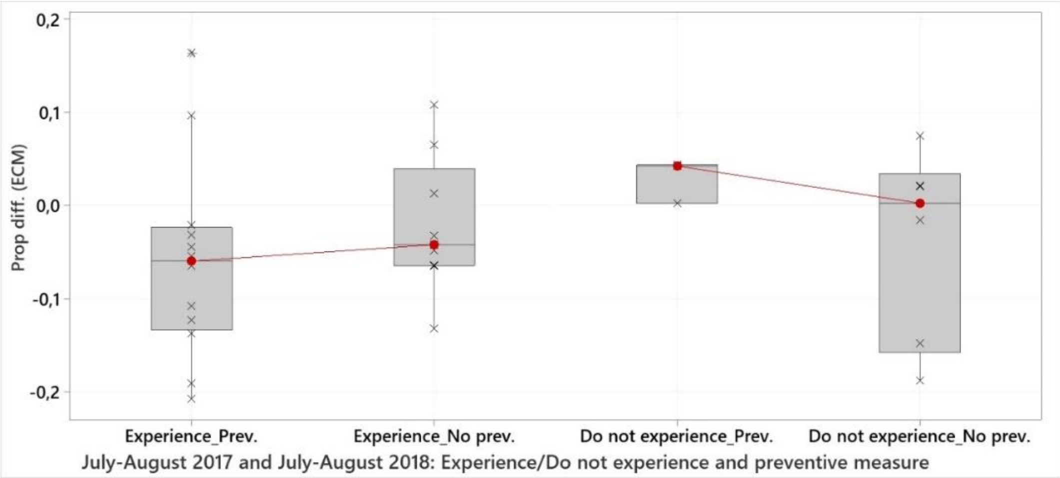

Figure 15. Boxplot of the factors: Experience and preventive measure Do not experience and preventive measures, showing the proportional difference in ECM between the four parameters (Experience_Prev., Experience_No prev., Do not experience_Prev. and Do not experience_No prev.). Inter-quartile range with 50% of the values, whiskers with 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

4.4.2. Signs of warm cows

When comparing the hot summer months 2018 with the seven-month period before, the Mann-Whitney results showed that the sign of warm cows that the farmer detect have no impact on ECM. However, farmers that described the cow as warm when they both panted and changed their behaviour had a median of 15.1% decreased ECM, compared to the farmers that described panted as a sign (8.2%) and the farmers that described changed behaviour as a sign (7.0%).

The farmers that detected warm cows when they panted had a positive impact on ECM with a statically significance ($p = 0.007$), when comparing the hot summer months 2018 with the same months 2017. The box plot shows that the parameter Panting had a median of +6.5% milk production, while the sign Panting and behaviour had -1.3% and the sign Behaviour -4.7% (Fig 16).

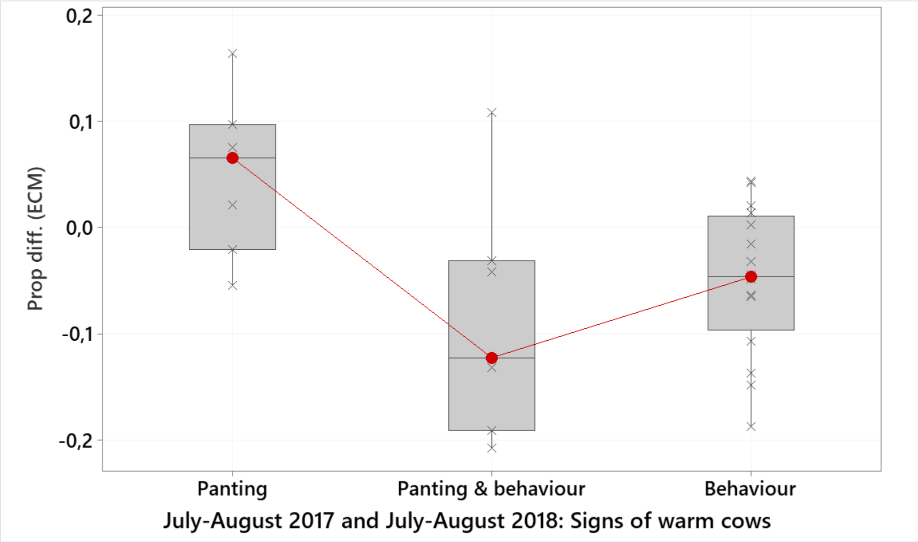

Figure 16. Boxplot of the factor: Signs of warm cows, showing the proportional difference in ECM between the three parameters (Panting, Panting & behaviour and Behaviour). Inter-quartile range with 50% of the values, whiskers with 25% of the bottom values and 25% of the top values, individual symbols (x) and a red median mark with connecting line.

5. Discussion

5.1. Structure of the study

5.1.1. The questionnaire and investigated factors

The interviews were held over phone without recording, meaning there was no possibility to go back in the interview if something were unclear afterwards. As always when it comes to interviews, questions might be understood differently depending on the one being interviewed. An example of this was the question of which ventilation they had; Mechanical, controlled or natural. Since controlled ventilation is a form of natural ventilation, some farmers answered that they had natural ventilation, even if warm housings always have controlled natural ventilation. This misconception was easy to correct, so the results in the analysis were not affected. Other misconceptions like this may have occurred but not been detected.

The questionnaire focused on various farm characteristics related to different systems and types of housing, but also about the farmer's experiences and strategies. It was mainly on this basis, in combination with the available literature, that factors to investigate were chosen. However, own ideas and thoughts on what might affect milk production during the summer 2018 were considered. An example is the construction year, which was chosen on the basis that older housings, between the years 1870-1999, were less adapted to today's standard and that the systems had lost its efficiency. However, this was shown not to be the case. A factor that was included at first was the effect of insulated roof. The reason it got removed was because the effect of insulated roofs was included in the warm buildings, since the warm buildings had insulated roofs and walls, while the cold housings did not.

Interesting factors to investigate would be the effect of sand on the ground in the laying area as one of the farms had or how stocking density is connected to heat stress during the summer. Furthermore, it would be to interesting examining the efficiency of different ventilation systems. This study just distinguished ventilations as natural, controlled natural and mechanical, which is a rough division of all the different type of ventilations used.

5.1.2. Comparing July-August 2018 with November 2017-June 2018

This approach was meant to provide a comparison between the "extreme" period (hot summer months July-August) in 2018 and previous farm production. However, no differences associated with the investigated risk factors was observed even though all farms except 2 experienced a drop in milk production during these months (Figure 1). This indicates that the observed drop is related to other, non-explored differences. For example, it may represent a seasonal decrease in milk production due to cows being released on pasture where they are exposed to changed feed ration, more heat and pathogens. The period November 2017 to June 2018 extends over half the summer period since the cows are released to the pasture in April. This means that the effect of three months of summer partly included in the average milk production for November 2017 – June 2018. In addition, the month May 2018 was also hot compared to a normal year, meaning that the effects of heat stress on milk production might also be included in this average daily milk production. This may have biased the results and made it harder to identify risk factors associated with heat stress.

5.1.3. Comparing July-August 2018 with July-August 2018

The only difference in milk production between these two periods is that one of them includes the effects of a very hot summer. Therefore, the comparison only includes the effects of the extreme heat 2018 and excludes the overall effects of a summer (such as differences in pasture and other management changes).

One thing to consider in this comparison is that some farms increase the milk production per cow annually, meaning that the results from the comparison of the effect of summer 2018 may be reduced. Also, if the farms were short on roughage during the summer 2018, cows may have been fed with more concentrates, resulting in a higher milk production that counteracted the decreased milk production due to heat stress.

5.2. Housing and systems

5.2.1. Warm and cold housings

Housing did not have a significant impact on the milk production during the warm summer month 2018. This is consistent with other studies that both have investing the overall difference in milk production between the systems (Schnier et al. 2003; Zähner et al. 2004) and the studies that been looking at the difference in milk production during heat stress levels (Lambertz et al. 2014).

However, the comparison between the normal summer 2017 with the warm summer 2018 shows an advantage for the warm housings with a smaller average drop in milk production (1.9% vs. 8.2%). These results agree with the study by Næss et al. (2011) which also found insulated warm housings superior to the uninsulated cold housings. The reason for this may be that the warm housing, due to the insulation, have a more even temperature both day and night, while the cold housings ambient temperature is more like the outside, with warmer days and cooler nights. As Zähner et al. (2004) states, in cold housings, the cool nights results in a stronger thermoregulatory response in the cow to lose the excessive heat from the day. However, during the summer 2018, maybe the nights was not cool or long enough for the cow to lose the excessive heat due to the extreme heat during the days, which result in a greater extent of heat stress. If this is the case, it matches the conclusion of Liberati (2009), claiming that the best way to reduce heat stress is insulated roof to eliminate the excessive heat during warm days. Also, the bigger difference in temperature between day and night in cold housings might also be a reason these farms got more affected. According to Ominski et al. (2002), sudden or acute heat is harder for the cow to handle since the animals have not adapted physiologically to the heat stress conditions

The uneven distribution between the housing systems (22 warm and 8 cold) have effect on the results and makes it hard to draw a justified conclusion. Although, of the 6 farms that was most negatively affected by the summer 2018 (with a decreased milk production of at least 10% in both approaches of comparisons), three of them were cold housings and three were warm housings. Based on these available numbers, this means that the risk of a cold housing being greatly negative affected by an extreme summer is 37.5 % (3/8) compared to 13% (3/22) for the warm housings.

It is reasonable that studies comparing type of housings effect on milk yield gives different results, since there are many factors that might be associated with both the type of housing and milk yield. Furthermore, the different climatic conditions between countries and the different structures of dairy production also affect the results.

5.2.2. The most frequent system: modern warm housing with controlled ventilation

Ventilation and year of construction did not have a significant impact on the milk production when considered separately, with only small advantages to the housings built after 2000 and the controlled ventilation could be observed.

However, when these factors (housing, ventilation and year) were combined to investigate the most common system among the 30 farms, which was the modern warm housing with controlled ventilation, a difference was observed. The results showed that the solution of modern warm housing with controlled ventilation had a significant impact on the milk production when summer 2018 was compared to the summer of 2017. This supports the main hypothesis that housing, ventilation and year of construction plays a role during warm periods, since farms with systems including these factors combined were the ones least affected by the extreme summer of 2018.

5.2.3. Milking system

When comparing the summer 2018 with the same months 2017 to find factors with effect especially during extreme heat, farms with AMS were less impacted by the extreme heat compared to farms with conventional milking systems. The average milk drop on farms with AMS was 1% compared to 6% on the farms with conventional milking system. Farmers with AMS in this study is in line with the conclusion by Speroni et al. (2006), that farms with AMS were more affected due to the changed behaviour in form of lowered activity and feed intake during times of heat stress. See three citations below from the interviews made in this study.

"The biggest challenge during the summer is to get the cows to the AMS."

"If the cows get really warm, it can be difficult to get them to the AMS."

"During the summer they are less active, which means lower milk production because they do not go to the robot."

Furthermore, a reason that the farms with AMS were less impacted during the summer 2018 in this study, may be that the cows in the conventional milking system had to stand crowded in the waiting area before being milked. This makes the cows warm and results in a higher degree of heat stress and negative impact on the milk production. Several farmers confirmed this during the interview and some of them tried to solve the problem by investing in extra fans in the waiting area or showering them with water in the waiting area. Below this concern is mentioned in citations from three of the farmers interviewed in this study with conventional milking systems.

"The cows get hot when I collect them for milking, so when it’s time for milking, we start an extra fan."

"When they're really hot, I shower the cows in water during the milking session."

"We have tried to increase ventilation during hot weather and shower the cows when they are to be milked.”

5.3. Preventive measures

5.3.1. Applying preventive measures

When comparing the summer 2018 with the summer 2017, the farms that did not apply any preventive measures had less negative impact on the milk production. The simple explanation for this may be that they did not need to, because as the results suggest, they were not as negatively affected by the summer 2018. This is in an agreement of what Dikmen et al. (2020) concluded when investigating if ventilation could be superior to sprinklers. The conclusion of the study was that a well-functioning and adjusted ventilation were superior to any measure.

5.3.2. Extra fans compared to shower and pasture management

A clear advantage could be seen for the farms with extra fans since they had on an average 4.1% increased milk production during the summer 2018 compared to the summer 2017, while the farms applying showering or pasture management an average 8.4% decrease in milk production (p=0.056). This tendency is in agreement with the second hypothesis that the use of extra fans during warm periods was the most efficient way to reduce the effect of heat stress on milk production. Also, the results partly agree with the literature, which are concluding that the combination of shade (indoors) with fans and sprinklers is the most effective way to reduce heat stress (Correa-Calderon et al. 2004; Calegari et al. 2015; Kendall et al. 2007; Armstrong, 1994; Silanikove et al. 2009; Kendall et al. (2007). Since sprinkler is much more common in the US and southern parts of Europe, the literature mainly applies both sprinklers and fans as a preventive measure to analysing the effects, which is not the case for any of the farms investigated. Below are two citations applying fans from the interviews made in this study.

"In the past, the big challenge was to keep the animals cool, but now fans have been installed. They will be started already in the spring to keep a more even climate in the stable."

"We got a fan in 2019. Now the flies are less annoying, the cows feel better, and the air in the stables is fresher."

Farmers applying showering as a preventive measure were the most negatively affected and had an average of 7% decreased milk production during summer 2018 compared to 2017. One reason for this might be that the farmers in this study only applied showering the cow with a hose as an emergency solution when the cow already is showing signs of heat stress in form of less milk production, and not applied as a preventive measure. While evaporative cooling using water is a well-used technique in other countries, it does not seem to be effective for the farmers in this study. The main reason for this might be that they do not use an actual sprinkler/misters but a water hose. Furthermore, the intervals for showering may not be long enough or occur with an inadequate frequency to result in any positive results on the milk production. Studies have confirmed that a higher frequency have a significant positive effect on the milk production (Kleinjan-Elazary et al. 2020). See citations below from farmers applying showering from the interviews made in this study.

"I Tried to make a shower last summer, which did not work so well, would be better to invest in fans, if the problem with weather repeats itself."

"We put up water hose as a sprinkler, but we didn't notice much difference. We probably needed to cover a larger surface to see a positive effect."

Only four farms applied pasture management as a preventive measure, and the effects varied a lot. Pasture management means that the farmer keeps the cows in shaded areas during the most extreme days, either by keeping the inside during the day and outside during the night, or by providing the cows with pasture that have shade. Studies confirms that providing shade is important for reducing heat stress in cows (Kendall et al. 2007; Veissier et al. 2018; Armstrong 1994; Tucker et al. 2008). Farmers from the interviews that applied this measure consider it as a useful and functioning measure, which agrees with another study on the effect of pasture management (Charlton et al 2013). Below, citations by two farmers that apply pasture management from the interviews made in this study.

"I have the animals outside at night instead, which solves a lot of problems!"

"We have them out during the night instead. We also have forest grazing that we open when the cows are very hot so that they get more shade, otherwise we will barely get them out. They like to walk in the forest, but the downside is that they don't milk so much then."

5.3.3. Experiences and acting preventive

Farmer that described their cows as warm and acted preventive had greater average milk production drop during the summer 2018 compared to both summer 2017 and the seven-month period before. This contradicts part of the last hypothesis, that farmer experience cows as warm and act preventative were better at handling the effects of heat stress on milk production. Since there were a great spread for farmers that did experienced their cows as warm and acted preventive, it can mean that just applying preventive when the cows are warm, does not necessarily lead to an increased milk production, but rather which preventive measure is chosen and during which signs of heat stress it is applied. This study also investigated the overall effect of preventive measures, which did not show a significant impact on the milk production during 2018. Therefore, this can be an explanation to why the result did not show a positive effect on the milk production when the farmers applied preventive measures when the cows showed signs of heat stress.

The reasons farmers that applied preventive measures got affected by the summer 2018 might be because they implement the preventive measures too late, when the cows are already in a state of severe heat stress with negatively affected milk production. As Zimbelman et al. (2009) stated, a high-producing cow is already adversely affected at a THI of 68, and preventive measures should therefore be implemented earlier to prevent heat stress. To clarify, THI of 68 can be a temperature of 22°C in combination of a relative humidity of 50%. This statement on when to apply preventive measures might be the reason why the two farmer that did not experienced their cows as warm but still applied preventive measure got average increase of 3% during summer 2018 compared to 2017. They simply applied the preventive measures before the cow got into a state of heat stress and therefore affected the milk production positively during the summer of 2018. The reason for the great spread of performance for the farmers that did not experienced the cows as warm, and therefore did not applied any preventive measures, might be that some miss the signs, and therefore get a bigger milk drop, while the farmers that perform well simply did not have cows that showed signs of heat stress and did not need any implementations.

5.3.4. Signs of warm cows

Farmers identifying warm cows by panting had a significant difference in milk production during the warm summer month 2018 compared to the summer 2017, with an average 6.5% increase in milk production compared to a decrease of 6.1% for the farmers that identified cows based on behaviour. Since panting is the earliest sign of heat stress, the result agrees with part of the third hypothesis, that farmers observing the early signs of heat stress were also better at handling the effects of heat stress on milk production. This result is in agreement with Brown Brandl et al (2005), stating that it is critical to have an early indicator of heat stress to not be adversely affected, and that respiration rate i.e., panting is the earliest and easiest to monitor and follow up on.

6. Conclusions

This study has investigated factors impacting the milk production during extreme summer heat. The results showed that the most successfully system for maintaining milk production under these conditions are modern warm housings with controlled ventilation. Furthermore, applying preventive measure does not necessarily mean a maintained milk production, but positive effects have been observed for implementation of extra fans. Also, observing early signs of heat stress was shown to have a positive influence of the milk production during a period of extreme heat. However, factors have different impact on different farms, meaning that the best solution can differ between farms based on their prerequisites.

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Appendix

Intervjuformulär VINTER

Intervjuare				
Datum	*XXXX-XX-XX*			
SE-nummer	*SE XXXX*			

Väder

	Drop-down	Fritext	Siffror

Upplevelse av extremväder

Vilket har varit ditt största problem kopplat till väder de senaste 3 åren?
Vilka konsekvenser fick det för din gårds:
Ekonomi?
Rekrytering av nya djur?
Djurhälsa?
Hur flexibel anser du dig vara att få tillräcklig mängd hemmaproducerat foder vid problem med långa perioder med värme, torka eller regn?

Vilka framtida problem ser du att extremväder skulle kunna orsaka för dig?

Sommarvärme

Är dina kor varma under sommaren?
Hur ser du om dina kor är varma?
Görs några åtgärder för att svalka korna?
Ifall ja, upplever du att dessa fungerar?
Vilken är den största utmaningen för dig i ditt arbete under sommaren?

Gårdsinformation:

Antal djur:		st
Antal mjölkande:		st
Vilken ras?		

(Om flera byggnader skriv: XXXX;XXXX;XXXX)

Byggnad och ventilation

	Mjölkkor	Sinkor	Ungdjur	
Vilket år byggdes byggnadena för dem olika djurgrupperna?				Kommentar:
Renoveringar? Vad gjordes och när?				

	Mjölkande	Sinkor	Ungdjur	
Typ				Kommentar:
Är taket isolerat?				

Underlag liggbås/liggplats (kryssa i samtliga)	Mjölkande	Sinkor	Ungdjur
	☐ Gummimatta	☐ Gummimatta	☐ Gummimatta
	☐ Madrass	☐ Madrass	☐ Madrass
	☐ Spalt	☐ Spalt	☐ Spalt
	☐ Cement	☐ Cement	☐ Cement
	☐ Djuptrö	☐ Djuptrö	☐ Djuptrö
	☐ Ströbädd	☐ Ströbädd	☐ Ströbädd
	☐ *Annat*	☐ *Annat*	☐ *Annat*

Mjölkningssystem

AMS:

Tillverkare					
Typ/modell					
Antal robotar		st			
Genomsnittligt mjölkningsintervall senaste månaden		timmar	ELLER		mjölkningar/dygn
Mjölkningar/Ledig tid %		%			
Andel Misslyckade/Ofullständiga mjölkningar		%	ELLER		stycken/dygn

Hur många kor per dag hämtas till mjölkning (genomsnitt senaste månaden)?		/dag
Tid innan hämtning/rutin kring hämtning		

Kotrafik	
Spendesinfektion?	
Om ja, vilket märke?	
Hur ofta byter du spengummi?	
Har du kontrollerat ditt systemvacum? Om ja, när?	

Konventionell:

Tillverkare	*Tillverkare*					
Typ						
Tid för mjölkning (från-till)	*fm*		*em*		*(tredje)*	
	från	*till*	*från*	*till*	*från*	*till*
Antal mjölkplatser		**st**				
Tid i väntefålla (max/i värsta fall)		**timmar**				
Finns nedskrivna rutiner för mjölkning?						
Spendesinfektion?		Vilket märke?				
Hur ofta byter du spengummi?						
Har du kontrollerat ditt systemvacum? Om ja, när?						
Handtvätt innan mjölkningen börjar						
Handskar						
Fuktig avtorkning av juver						
Torr avtorknig						
Urdragning innan mjölkning						
Urdragning i kontrollkärl						
Organ för nykalvade?						
Organ för sjuka kor?						

Juverhälsa

Har du haft mastiter (subkliniska eller kliniska) senaste månaden?				
Kliniska mastiter:				
Antal nya djur med kliniska mastiter senaste månaden?		**st**		
Subkliniska mastiter:				
Antal nya djur med höga celler senaste månaden?		**st**		
Vanligaste orsaken (bakterien) till mastit senaste månaden? *(Upplevd)*				

Utfodring Mjölkkorna

	I bästa fall	**I värsta fall**		
Hur många timmar per dygn har korna tillgång till grovfoder? *(senaste månaden)*			**Timmar**	

Om fullfoder:

Vilka fodermedel ger du de mjölkande korna?	Fodermedel			
Foder som köps in	Produktnamn	Leverantör		
Mineralfoder som köps in:	Produktnamn	Leverantör		
Är det möjligt att få recept på blandfodret?	Be dem maila dokument eller foto på leveranskvitto			

Om blandfoder

Vilka fodermedel ger du de mjölkande korna?	Fodermedel			
Foder som köps in	Produktnamn	Leverantör		
Mineralfoder som köps in:	Produktnamn	Leverantör		
Individutfodrat kraftfoder:				
Hur mycket kraftfoder går åt på en dag?	Kg per ko	ELLER	Totalt per dag	Antal kor som
Är det möjligt att få recept på blandfodret?	Be dem maila dokument eller foto			

Om separat utfodring grovfoder och kraftfoder

Vilka fodermedel ger du de mjölkande korna?	Fodermedel			
Foder som köps in	Produktnamn	Leverantör		
Mineralfoder som köps in:	Produktnamn	Leverantör		
Uppskatta mängden grovfoder som går åt till mjölkkorna på en dag		ELLER	Kg TS/ko	ELLER
Hur mycket kraftfoder går åt på en dag?		Antal kor som får fodret	ELLER	Kg per ko
	1a kalvare:	**Äldre djur:**		
Hur mycket kraftfoder får korna 1 månad efter kalvning?			**Kg per ko**	

För samtliga typer av utfodring:

Finns foderanalys för det grovfoder som korna har ätit den senaste veckan?					
Hur mycket salt går åt på en vecka?					
"Målavkastning" utifrån denna foderstat?	**1a kalvare:**	**Äldre djur:**			
			ECM		
	Foderkvalitet (näringsinnehål	**Foderhygien:**			
På en skala från 1-10 (där 1=botten och 10 =toppen) hur upplever du:					

Vatten

Källa					
Om egen brunn: Hur är vattentillgången nu?					
~~Upplever du problem med vattentillgång just nu?~~		~~Varför:~~	~~*Fritext*~~		~~*Flytta till somma*~~

Reproduktion

Använder du regelbundet djurflödesrådgivning?		Kommentar:			
Hur har brunstpassning gjorts senaste månaden? ☐	Automatisk:				
☐	"Manuell" observation av djur				
☐	Annat:				
Om manuell: När har brunstpassning utförts senaste månaden?					
☐	Löpande under arbetet bland djuren				
☐	Fasta tider:				
☐	Annat:				
Hur många kor har inseminerats senaste två veckorna?		st			
Med vilken metod har detta gjorts? ☐	Djurägarsemin ☐	*Assistentsemin*	☐ Betäckt med tjur		
Uppskatta andelen semin och naturlig betäckning:	Djurägarsemin		%		
	Assistentsemin		%		
	Betäckt med tjur		%		
Varifrån köps seminen?					
	Förstakalvare	**Äldre djur**			
När startar ni brunstpassning efter kalvning?			*Senast 30 dagar efter -*		
Har brunstpassningen påbörjats efter X dagar den senaste månaden?					
Om nej, varför?					

	I bästa fall				
På vilka tecken inseminerar du? ☐	Stå brunst ☐	Svankar ☐	Flytning ☐	Upphopp ☐	Oro
☐	Svullnad/rodnad blygd ☐	Håller mjölken ☐	Minskad aptit ☐	Aktivitet ☐	Annat:
	I värsta fall:				
☐	Stå brunst ☐	Svankar ☐	Flytning ☐	Upphopp ☐	Oro
☐	Svullnad/rodnad blygd ☐	Håller mjölken ☐	Minskad aptit ☐	Aktivitet ☐	Annat:
Hur kontrolleras dräktigheter? ☐	Brunstkoll efter seminering				
☐	Dräktighetsundersökning	Tid efter			
☐	Annat sätt:				
Om dräktighetsundersökning:					
Används ultraljud?	☐ Ja	☐ Nej	☐ Ibland		
Används dräktighetsanalys?	☐ Ja, 2 tillfällen	☐ Ja, 1 tillfällen	☐ Nej		
Rekrtyeringsprocent?		%			
Fördelar du kalvningar med hänsyn till säsong/årstid?					
Om ja, hur och varför:					

Framtida strategier för att minska effekterna av extremväder

Finns det några investeringar du skulle vilja göra?	
Vad skulle kunna motivera dig att testa åtgärder/göra förändringar?	
Var eller av vem söker du stöd innan du genomför förändringar?	
Vad kan mjölkindustrin i stort göra för att hjälpa dig?	