The Importance of Shade for Dairy Cattle in Sweden

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Institutionen för husdjurens utfodring och vård

Examensarbete 287
30 hp E-nivå

Swedish University of Agricultural Science
Department of Animal Nutrition and Management

Uppsala 2009

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Preface

This master thesis was conducted at Kungsängen research centre in Uppsala at the Department of Animal Nutrition and Management. It was funded by the Royal Swedish Academy of Agriculture and Forestry (Kungliga skogs- och lantbruksakademien). Per Peetz Nielsen acted as supervisor and Jan Bertilsson as examiner from the department. The overall aim of the study was to evaluate the importance of shade for dairy cattle in Sweden. The study is divided into two parts where this thesis is focusing at the behavioural part. Karin Ulvshammar will complete her master thesis in the spring of 2010, where she will concentrate at shade and its effect on milk production.

Uppsala in December 2009

Maria Andersson

Abstract

Today, there are no regulations saying that cows must have access to some kind of shelter at pasture during the summer. In more tropical countries, it is well-known that dairy cows might suffer from heat stress when exposed to sun and high temperatures. The well-being of the cows is thereby reduced and the production may also decrease. In Sweden, no research has been done in the area and therefore it is now a clear need of improved knowledge.

The purpose of this study was to investigate the importance of shade for dairy cows in Sweden. The behaviour of 30 cows was examined to see any differences between cows with access to shade and cows without access to shade. The cows were divided into two groups with fifteen cows in each group. At pasture, one group had access to shade in a tent (group 1) and the other group did not have access to shade (group 2). Behavioural observations were carried out at thirteen occasions, including four 24-h-periods. The behaviour of all cows and whether they were positioned in shade or not were recorded in 10-minute intervals. The microclimate was measured at regular intervals of 10 minutes using HOBO dataloggers, and Temperature-humidity index (THI) was calculated from the ambient temperature and relative humidity. The milk yield was measured at each milking and when the temperature outside was high, milk samples were taken to measure the components and the somatic cell count of the milk. Grass samples were also taken to measure the quantity of pasture in dry matter content and energy as well as the grass components.

The results showed that cows starts using shade at a THI of 66.9 and their shade use increased as THI increased. They used the tent in average 14.5 % of the time per day between 9 am to 7 pm. The most common behaviour within the shade was standing. As THI increased, grazing behaviour declined, and to compensate this they grazed to a higher extent during the night. The cows also stood up, moved around and lied down to a higher extent when THI increased. The cows grazed to the highest extent between 5 pm and 10 pm, and lied down to the most between 2 am and 6 pm. The group without shade showed the highest frequency of both grazing and lying.

These results indicate that dairy cows in Sweden prefer to use shade if available when the temperature and relative humidity is high. However, more research is needed to see if the well-being is reduced by the absence of shade.

Sammanfattning

I nuläget finns det inte lagstiftat att mjölkkor i Sverige ska ha tillgång till skydd från solen när de går på bete. I varmare och tropiska länder är det dock välkänt att kor kan drabbas av värmestress om de utsätts för sol och höga temperaturer. Välfärden blir då nedsatt och även mjölkproduktion kan sjunka. I Sverige finns det än så länge ingen forskning inom det här området och därför är det viktigt att nu börja belysa problematiken och öka kunskapen.

Syftet med det här arbetet var att undersöka betydelsen av skugga för mjölkkor i Sverige. Beteendet på 30 kor studerades därför för att upptäcka några eventuella skillnader mellan kor med tillgång till skugga och kor utan tillgång till skugga. Korna blev uppdelade i två grupper med femton kor i varje grupp. När korna gick på bete hade ena gruppen tillgång till skugga (grupp 1) och den andra gruppen hade inte det (grupp 2). Beteendestudier utfördes vid tretton tillfällen, inklusive fyra tillfällen när korna observerades ett helt dygn. Beteendet för alla kor samt om de befann sig i skugga eller inte registrerades var 10:e min. Mikroklimatet mättes var 20 min under hela perioden med hjälp av HOBO dataloggar, och temperature-humidity index (THI) räknades ut från omgivningstemperaturen samt den relativa fuktigheten. Mjölkmängden mättes vid varje mjölkning och när temperaturen utomhus var hög mättes även mjölksammansättningen och bakterieantalet. Gräsprover togs vid varje fållbyte för att mäta energiinnehållet och betesmängden.

Resultaten visade att korna började använda tältet när THI låg på 66.9 och de använde tältet mer ju högre THI var. I genomsnitt använde de tältet 14.5 % av tiden mellan 9 och 19. Det vanligaste beteendet under skugga var att stå upp. När THI ökade, så minskade betesbeteendet och för att kompensera detta så betade de i en högre grad på natten. Korna stod även upp, rörde sig mer och låg ner i högre grad när THI ökade. Korna betade som mest mellan 17 och 22, och låg ner mest mellan 2 och 6 på natten. Gruppen som inte hade tillgång till skugga både låg ner och betade mest.

Den här studien indikerar att mjölkkor i Sverige föredrar att använda skugga om det finns tillgängligt när utetemperaturen och luftfuktigheten är hög. Dock så behövs det mer forskning för säga om välfärden på korna är nedsatt på grund av att korna inte har tillgång till skugga.

Introduction

According to the Swedish legislation, female cattle older than six months must have access to pasture between two to four months during summertime. But today, there are no regulations saying that they should be provided with some kind of shelter from the sun at pasture. (DFS, 2007). In other countries, for example New Zeeland, research has been conducted showing that cattle prefer using shade if available. The well-being of cows is improved by the shade since the risk of suffering from heat stress is reduced. However, earlier studies have focused on a tropical climate with hot and humid conditions, and there is now a clear need of improved knowledge in how dairy cows are affected by the Swedish summer climate concerning their well-being and production.

All living creatures have their thermoneutral zone, i.e. the temperature interval where their comfort and well-being is maximized. Beyond that zone, animals may start suffering from heat stress and their comfort is affected. For dairy cows, the zone is stated to be 5-25^{o}C and above that temperature, different responses will start to cope with the heat stress. For example, cows might reduce their feed intake which will lead to a decreased milk production. Their behaviour and diurnal pattern can also be disturbed which affects both their well-being and production. In many countries this is already a problem, and along with the greenhouse effects and the raising average temperatures it will increase even more. And therefore, it is of importance to enlighten this problem and find alternatives to avoid heat stress.

Nowadays, the world is facing large global changes considering the green house effects and its consequences. The earth is warmed up and the temperature is constantly increasing, and therefore it is of even higher importance that new techniques are invented and solutions are found to manage this heat stress problem.

Aim and hypothesis

The overall aim of this experiment is to determine the importance of shade for dairy cows considering behaviour, physiology and production in Sweden. It will also contribute to a better knowledge in how the dairy cows are affected by heat stress in Swedish conditions.

Thus, the hypothesis tested in this experiment is: dairy cows in Sweden will use shade if available when the temperature and solar radiation is high and this will lead to positive effects considering the production and their well-being.

Literature survey

Heat stress

Heat stress is a common problem in countries with hot and humid climates and occurs when the cow produce or absorb more heat than she can dissipate. It can be shown in different physical responses: reduced feed intake, increased water intake, changed metabolic rate and maintenance requirements, increased evaporated water loss by sweating and panting, increased respiration rate and heart rate, changed blood hormone concentration and increased body temperature. The cow might also seek shade and wind (Bucklin *et al.*, 1991; Kadzere *et al.,* 2001).

The environmental conditions are the major source contributing to heat stress and there are four factors that affect the ambient temperature: air temperature, relative humidity, air movement and solar radiation (Buffington *et al.,* 1981). These conditions can cause the effective temperature to be higher than the cow's comfort zone, leading to heat stress (Armstrong, 1994). The ambient and effective temperature is explained as the temperature of the surroundings and the combination of the ambient temperature and wind speed, respectively.

Beede and Collier (1986) suggested some management procedures to reduce the thermal stress; physical modification of the environment, genetic development of the breeds that are less sensitive to heat, and nutritional management. This thesis will only cover the modification of the environment.

The thermoneutral zone

The thermoneutral zone (TNZ) is explained as the zone of minimal heat production at normal rectal temperature. Within that zone, there are minimal physiological costs and maximum productivity (Du Prezz *et al.*, 1990). The TNZ can vary between animals, and it generally depends on factors like age, species, feed intake, diet composition, housing system and behaviour. When cows have a high metabolic heat increment, they require an effective thermoregulatory mechanism to maintain body temperature. The metabolic heat production rise from the metabolism of nutrients and because of this, the heat load is increasing (Kadzere *et al.*, 2001). The TNZ ranges from the upper critical temperature (UCT) to the lower critical temperature (LCT) and it appears rather difficult to point out the exact limits, especially for LCT, since there are many factors affecting it. However, Berman *et al.*, (1983) stated the UCT to 25-26^{o} C, a limit to which the cow can maintain a stable body temperature before entering hyperthermia and become heat stressed. When that temperature is exceeded, the cow increases in body temperature since she is not capable of cooling down. According to Hamada (1971), the LCT is given as a range from -16^{o}C to -37^{o}C for cows producing 30 kg of FCM/day, but the comfort zone is probably regarded to be set higher. The TNZ is explained in Figure 1.

The cow can besides the physical responses loose heat by radiation, conduction, convection and evaporation (Berman *et al.*, 1985). Radiation, conduction and convection are categorized as sensible heat transfer or non-evaporative cooling, and evaporation as latent heat transfer. Radiation can be explained by the process where energy or heat is emitted from one body (cow) and transmitted trough a medium (air) and then absorbed by another body. A dark object absorbs more than a light one. Conduction is an exchange of heat by two objects in direct contact and convection can be explained by the transfer of heat through a fluid caused by molecular motion (Kadzere *et al.,* 2001). When the cows temperature is rising, and is approximately the same as the ambient temperature, the non-evaporative ways (radiation, conduction, convection) of cooling becomes less effective and the cow must start evaporate the heat by sweating and panting. However, this is obstructed when the relative humidity is high. Often, it is the combination between a high ambient temperature and high relative humidity that is a problem for heat stressed cows (West *at al.,* 2003).

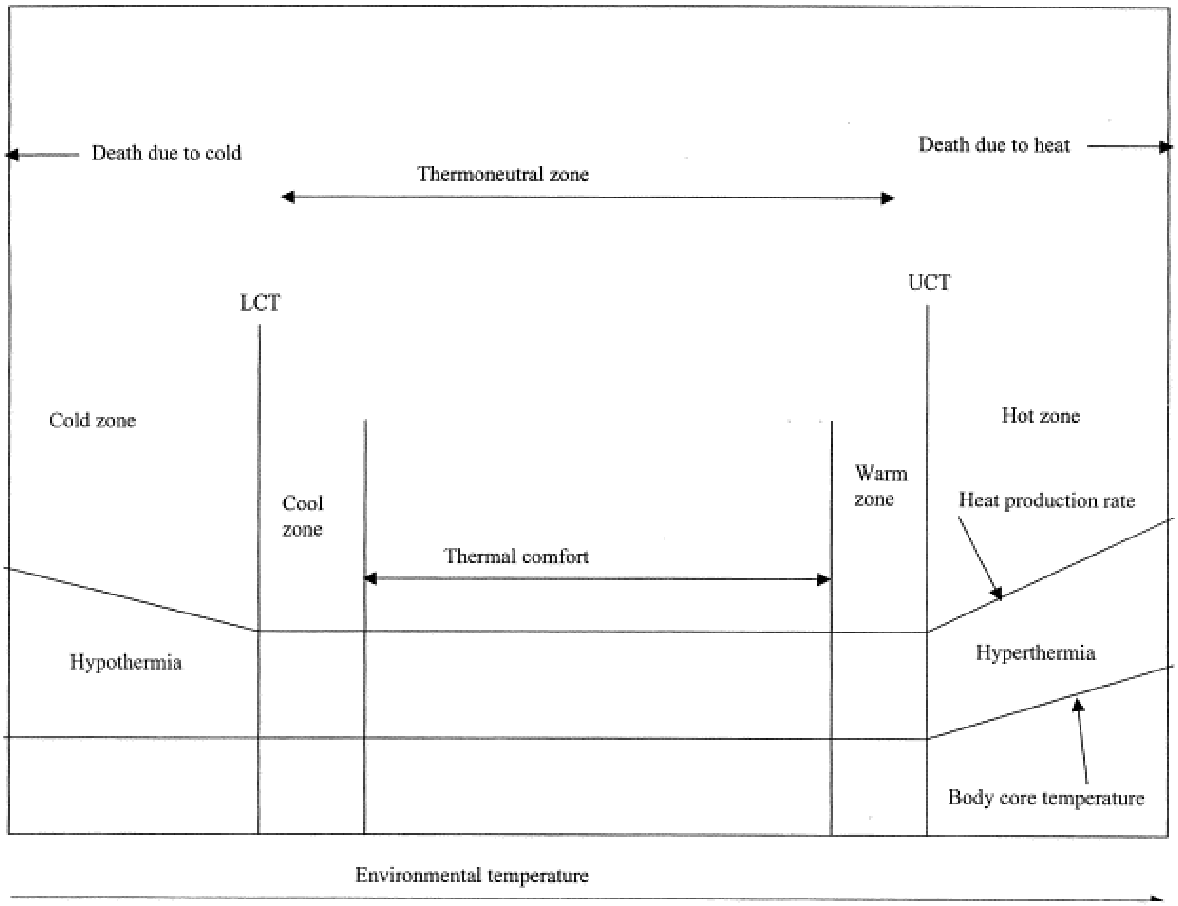

Fig. 1*. A schematic picture of the relationship between the cow's body temperature, heat production and environmental temperature (Kadzere et al., 2001).*

Temperature-humidity index

A way of measuring the thermal climatic conditions is to use the temperature-humidity index (THI). This is calculated from the wet (W) and dry (D) bulb air temperatures for a particular day as follows:

$$THI = (1.8 \times T + 32) - ((0.55 - 0.0055 \times RH) \times (1.8 \times T - 26))$$

where T is the air temperature (^{o}C), and RH the relative humidity (%), (Tucker *et al.,* 2008). The critical values for THI in dairy cows are determined as 64 for minimum, 72 as the mean value and 76 as the maximum. A THI-value of 72 equate to 25^{o}C and 50% relative humidity. If the THI-value exceeds 72, the cow might start suffering from heat stress and the milk production will decline (West *et al.*, 2003). When the value is between 78 and 82 the cow is severely affected and cooling is essential. If above 82, the cow might die from heat stress (Du Prezz *et al.*, 1990).

The behaviour of cattle

The behaviour of cattle can be separated into six different categorizes; nutritional, resting, locomotion, social, reproductive and maternal behaviour. The most common behaviours in these categorizes are shown in Fig. 2 (Phillips, 1993). Reproductive and maternal behaviour are not of importance for this thesis and will not be looked at attentively.

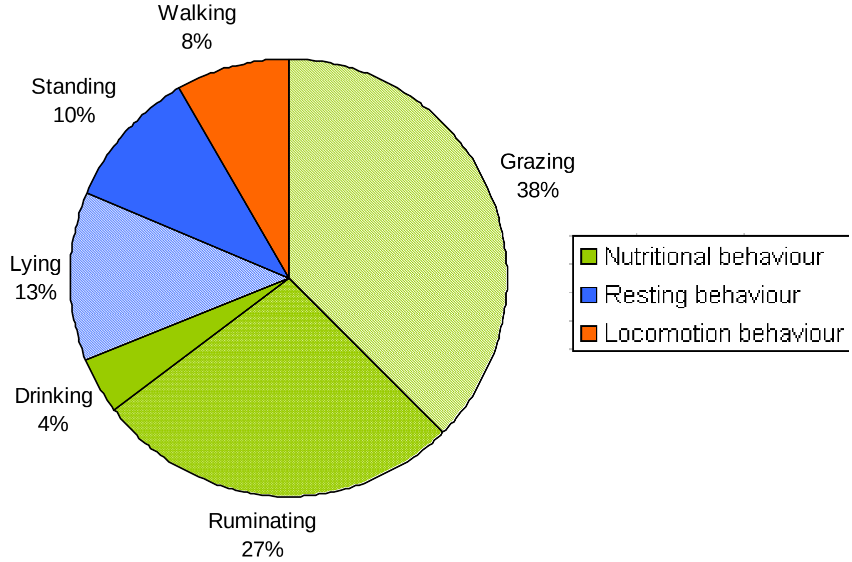

Fig. 2. *The distribution of behaviours performed during 24 h for a high-yielding dairy cow (Phillips, 1993).*

Nutritional behaviour

Within this category the activities around obtaining nutrients are involved, and mainly it refers to feeding/grazing, rumination, drinking, defecation and urination.

Grazing

In average, dairy cattle spend about 9 h per day grazing and this can be divided into normally five bouts. Each of these bouts lasts for approximately 110 minutes, but the variation can be high. The first bout is occurring shortly after dawn, followed by two to three bouts between the milkings and the last one in the evening around dusk (Phillips, 1993). Cows are crepuscular, meaning that they are mainly active at sunrise and sunset, indicating that these two bouts are the longest and most intense (Albright and Arave, 1997; Gibb *et al.*, 1998).

Generally, cattle prefer to graze dense and dark-green pastures which indicate a greater bite weight and high nitrogen content. When the temperature or humidity is high, easily digestible feed is to prefer over more fibrous feed since fibre produces more heat increment of digestion. During evening, the bite rate is maximal and the chewing rate minimal, indicating that the cow maximize their intake at that time (Phillips, 1993). This might be because of the lower air temperature (Taweel *et al.*, 2005). Cows do not eat close to faecal deposits, and in the end of the pasture season about 2-4 % of the herbage is contaminated (Phillips, 1993).

A change in grazing times depends on the quality of the pasture, climatic factors like sun, rain, wind, and the competition of the herd mates (Fraser, 1983). Nutritional requirements and the access of supplementary feed are also of great importance. It was shown that when cows were offered supplementary feed, their grazing time was reduced from 7.7 h/day to 6.4 h/day (Phillips, 1993). The grazing time varies between days, but the between-cow variation is higher than the between-day variation. However, during the evening and at night the between-day variation can be very high (Phillips and Denne, 1988). The grazing times are also increased when the pasture quality declines (Albright and Avare, 1997).

When the temperature humidity index (THI) is increasing as well as the rectal temperature and the cow suffer from heat stress, the feed intake is decreased (Kadzere *et al.*, 2002; West *et al.*, 2003; Taweel *et al.*, 2005). It is most obvious that cows have a decreased feed intake when the temperature exceeds 25^{o} C, and especially in the afternoon (Taweel *et al.*, 2005). A way of limiting the exposure of sun during the day is to increase the time of night grazing and by this, the heat load is reduced. However, cows are usually diurnal feeders and in a study from New Zeeland, it was shown that cattle normally graze approximately 85 % during the day, and 15 % at night (Albright and Arave, 1997). In extremely hot areas, about 60 % of the grazing can be done at night (Phillips, 1993). When cows graze to a greater extent during night, it results in a higher feed intake and an increased milk yield in the morning (Kendall *et al.*, 2006).

Ruminating

When ruminating, cows are relaxed and quiet, having their heads down and the eyelids lowered. Usually they lie down with their chest to the ground, but sometimes they stand up (Albright, 1987). The cow is ruminating for approximately six to seven hours per day, divided into about 15-20 bouts. The duration of the rumination can differ to a great extent; between a few minutes to one hour (Fraser, 1983). Usually, the rumination is performed in connection with the grazing times and with the most intense period several hours after dusk. The rumination time depends on the feeds fibre content. The more fibrous feed, the longer rumination time (Phillips, 1993). When cows lay down during rumination, they prefer to lie on their left side. The rumen is positioned on the left side and therefore the rumination will be the most effective (Grant *et al.*, 1990).

When the ambient temperature is rising, the rumination is decreased. In a study by Tapki (2005), it was stated that the rumination decreased from 18.1 % in the morning to 14.6 % in the middle of the day. However, protection from sun may prevent this. Shultz (1984) showed that a shade structure increased the rumination compared to non-shaded cows, when the temperature was around 35-40^{o}C. Blackshaw and Blackshaw (1994) also stated that the rumination is increased if the cows have access to shade. It is also clear that a high producing cow ruminate less than a low producing when the ambient temperature is high. One explanation for this is that the cows produce a lower rate of metabolic heat if they ruminate less (Kadzere *et al.*, 2002).

Drinking

Cattle drink about two to five times a day, corresponding to about one hour. They synchronize drinking with the feeding bouts, and this is most obvious in early morning. There is also a peak in drinking behaviour when being returned to the pasture after milking (Phillips, 1993). Cardot *et al.*, (2008) showed that the three-fourths of the water intake occur between 6 am and 7 pm. It is important that feed and water is available under the shade, otherwise the cow must choose between staying under shade or eating and drinking. This might lead to a lower water and feed intake and to a decreased milk production (Bucklin e*t al.,* 1991).

The water intake is affected by several factors; average ambient temperature, milk production, dry matter intake (DMI), dry matter content of the ration, body weight, lactation number, day in lactation, Na intake and K intake all shows a positive correlation to water intake (Meyer *et al.,* 2004). However, the most obvious factors affecting water intake is the dry matter content of the ration, DMI, milk production and the ambient temperature (Holter and Urban, 1992; Meyer *et al.*, 2004). The higher dry matter content in the ratio, the more water is consumed (Phillips, 1993). During the summer, the water intake is increased compared to during the winter (Holter and Urban, 1992), and the water intake increase with 1.52 kg/day for each degree Celsius of increase in ambient temperature. (Meyer *et al.,* 2004). When comparing high-producing and low-producing cows, it is shown that high-producing cows have a faster dehydration rate (Maltz *et al.,* 1994).

Predicting the water consumption has been shown to be rather difficult. Holter and Urban (1992) found that cows drink about two times their milk yield, Cardot *et al.,* (2008) state that three times their milk yield is more correct and a study by Meyer et al., (2004) showed a need for 1.3 litres of water per produced kg milk. According to Cardot *et al.,* (2008) free water intake (FWI) (l/d) can be calculated as follows: 1.53 × dry matter intake (kg/d) + 1.33 × milk yield (kg/d) + 0.89 × dry matter content (%) + 0.57 × minimum temperature (°C) − 0.30 × rainfall (mm/d) − 25.65. A study by Wredle and Spörndly (2005) showed that dairy cows in an automatic milking system drank about 35.2 litres of water at pasture per day when offered water both in the barn and at pasture.

When cows are suffering from heat stress it may also have a direct impact on the cows comfort when drinking water. This is because of its direct cooling of the reticulum. Finally, the thermal load will also be decreased (Beede and Collier, 1986).

Defecation and urination

Cattle defecate about 12 times a day, and it can be performed when the animal is walking, standing, grazing, lying or getting up. Mainly, they defecate when they stand up after a period of lying or when grazing. The cattle reject areas with faecal deposits when grazing and this might lead to a decreased feed intake if the cows are forced to spend much time searching for feed. Cattle urinate about ten times a day and mainly when grazing. At pasture, cattle prefer to graze herbage that has received a deposition of urine. This might be because of the increased sodium content (Phillips, 1993).

Resting behaviour

Resting behaviour includes both lying and standing. Lying is a highly motivated behaviour for cows and is used for rest, rumination and company. The cow is mainly sleeping with its head tucked round against the thorax (Phillips, 1993). In average, dairy cattle spend about 8-15 hours per day lying down (Tucker *et al.,* 2009). In daylight, about 60 % of the time is spent lying. During darkness, the corresponding amount is 59 % (Albright and Avare, 1997). About 55 % of the total time spent lying occurs between 22:00 and 04:00. Normally, a cow stands up after two hours of resting and then lies down again, usually on the other side (Albright, 1987).

According to Ruckebuch (1972) there are four different levels of alertness: alert wakefulness (AW), drowsiness (DR), quiet sleep (QS) and active sleep (AS). The most common grade for cows are DR (about 50 %) and they are asleep (QS or AS) about 16 % of the day, and mainly during night time. The drowsiness is divided into about 20 periods each day and the true sleep is following these periods (Fraser, 1983). According to Albright (1987), cattle are in this drowsy state for about 7 to 8 hours per day and the true sleep is for about 4 hours.

Cows without access to shade spend less time lying and more time standing as the temperature increases (Matias, 1998). If the temperature at the ground surface is higher than the cow, the conduction is increased between the cow and ground and thereby the thermal load will increase. Instead, when standing, they maximize the evaporation from the body surface and the distance between the blood vessels and the surface will be greater. The convection is also increased due to the wind (Igono *et al.*, 1987). Albright and Arave (1997) also pointed out that the decreased time of lying when high temperatures might be because of restlessness. However, if cows have access to shade, their lying time is increased within the shade. The lower temperature at the surface will be transferred to the cow through conduction and make the cow more comfortable (Marcillac-Embertson, 2008; Shultz, 1984). Also, when cows spend the majority of their time under shade, they concentrate their defecation and urination in this area, which increase the ground moisture and decrease the surface temperature (Marcillac-Embertson, 2008).

Locomotion behaviour

Locomotion behaviour refers to voluntary movements which displace the whole body, such as walking, trotting, galloping, jumping and cantering and is primarily forward motion. Cows spend about two hours of walking each day. Cattle are motivated for locomotion when they for example demand food, water, shelter, grooming, more space or a sexual partner. Individual animal factors like genetic and physiological state as well as the climate and environment is also of importance (Phillips, 1993).

When the THI and the temperature were high, Schütz *et al.*, (2008) found that cows moved around more. They might feel some kind of restless and discomfort. In contrast, Tapki and Sahin (2006) stated that high producing cows moved less than low producing in order to balance their body temperature. Locomotion requires metabolic work which will increase the metabolic heat increment. Neither way, it is clear than the animal feel some kind of distress when THI and temperature is high.

Social behaviour

Due to cattle's social interactions they are able to communicate widely with each other. When they first meet, they undergo a part of exploration, which then is followed by recognition. When their positions are established, the communication can begin and further on the bonding between animals. Communication includes visual, olfactory, tactile and vocal communication. Cattle then form a kind of social organisation with a dominance order and groups (Phillips, 1993). Re-grouping of animals disturbs this order, and aggressive behaviours might occur. This can be expressed as both avoiding and fighting behaviours. However, the aggressive behaviour normally declines after a new dominance order is established (Kondo and Hurnik, 1990).

Grooming is a kind of tactile communication and means body care of the cow. There are both self-grooming and allo-grooming. The allo-grooming is most performed at the head and the upper part of the cow and it is a way to establish rank-order. Often it is the cows with equal rank that groom each other most frequent. Average social grooming (receiving or giving) occurs 2.1 times per day (Albright & Arave, 1997). The frequency of allo-grooming is often increased during oestrus and is then a kind of sexual behaviour. Cows mounting each other are also signs of oestrus and sexual behaviour (Phillips, 1993).

Böe and Faerevik (2003) pointed out that space allowance is of great importance for the social behaviour. If not enough space, there might be an increase of aggressive behaviour. A study by Mitlöhner *et al.,* (2002) shows that agonistic behaviour occured less for shaded cows than unshaded, and bulling also occured less for shaded than unshaded cows at 9 pm.

Use of shade

In hot and humid climate, it is shown that cattle prefer to use shade if available when exposed to high temperature and solar radiation. This is more obvious at high temperatures, and especially in the middle of the day (Tucker *et al.,* 2008; Kendall *et al.,* 2006). A study by Fisher *et al.* (2008) showed that cows start using shade when the temperature is above 25^{o}C. Another study by Langbein and Nichelmann (1993) says that the critical temperature when the cows stopped grazing and searched shade was 28^{o}C. However, since cows also use shade at lower temperatures this demonstrates the importance of shade even more (Schütz *et al.,* 2009; Tucker *et al.,* 2008).

Cows also prefer to use shade that offer a greater protection from solar radiation. For example, 50 and 99 % blockage is preferred instead of 25 %. 50 and 90 % blockage might be so similar that cows are not able to distinguish between them (Schütz *et al.,* 2009). When measuring the motivation for shade by giving cows the opportunity to choose between standing in shade or lying in the sun after lying deprivation for 12 h, the cows preferred to stand in shade despite their normally high motivation for lying (Schütz *et al.,* 2008).

Shade has also been shown to be a successful way to reduce the heat when compared to other techniques. When comparing shade and sprinklers it was shown that shaded heifers had a higher feed intake, increased average daily gain and increased feed efficiency than the heifers with sprinklers. Shaded heifers also had a lower respiration rate than unshaded (Marcillac-Embertson *et al.,* 2008). If cows have access to shade, the radiant heat load can be reduced with 30 % or more. Some research says that water is a substitute for shade, but shade has been shown to be more effective to reduce heat stress (Blackshaw and Blackshaw, 1994). There are various types of roofing materials and according to Buffington *et al.,* (1983) the most effective is a reflective roof such as aluminium or galvanized with isolation beneath the metal. There should also be a concrete floor to keep the shaded area as clean as possible. The shade structure should provide each cow with at least 4.2 m^2 of floor space, but preferably 5.6 m^2. It may not be of economical benefit to invest in such expensive shade structure and a study by Valtorta *et al.,* (1997) shows that an 80 % shading cloth was effective in reducing the heat load and floor temperatures.

A study by Lanbein *et al*. (1993) showed that there are some behavioural differences between breeds. The behaviour of purebred Holestein and zebu crosses was compared between the rain season, when the temperature and relative humidity was higher, and the dry season. Holstein cows decreases their daily grazing time in the rain season by 72 % compared to the dry season, and increased their time spent in shade by 45 %. The zebu crossings on the other hand decreased their grazing time by only 60 % and increased their time in shade by 30 %. This shows that pure breed Holsteins are more easily affected by high temperatures and heat stress.

In general, there are some genetically differences to what breeds that are more tolerant to heat stress. Bos indicus breeds are more resistant and can regulate the heat better than Bos taurus breeds. This is due to differences in metabolic rate, food and water consumption, sweating rate, coat characteristics and colours (Blackshaw and Blackshaw, 1994). When measuring the respiration rate between purebred zebus and Friesian-zebu crosses, it was shown that the crossbreed had a higher respiration rate. However, there were no differences in rectal temperature (Roman-Ponce *et al.,* 1976). The same results were found by Matias (1998), where purebred Holstein had a significantly higher respiration rate compared to crossbreds (Holstein X Sahiwal). The crossbreds also grazed more than the purebred during the hottest time period.

The conception rate has also shown to be better when cows have access to shade. A study by Roman-Ponce *et al.* (1976) showed a difference of 44.4 % (54 services) and 25.3 % (75 services) for the conception rate for shaded and non-shaded cows.

Respiration rate and body temperature

Respiration rate and body temperature has been shown to be a valuable indicator of heat stress, and is more commonly used than heart rate. Heart rate seem to be the same during winter and summer and it is uncorrelated with the environmental temperature (Lemerle and Goddard, 1986). The normal respiration rate and body temperature for a cow is 30 breath/min and 38.6^{o}C, respectively (Björnhag *et al.*, 1989). When the animal suffers from heat stress, the respiration rate and rectal temperature increase (Bucklin *et al.*, 1991; Fisher *et al.,* 2008). Berman *et al.,* (1983) showed that cattle are able to maintain a stable body temperature up to an ambient temperature of 25 to 26^{o}C. At higher temperatures, the respiratory frequency rose to between 50 and 60 breaths/min. According to Lemerle and Goddard (1986), the rectal temperatures increases when THI is above 80 and respiration rate when THI is above 73 and more steeply at 80.

When cows are protected from sun, their mean body temperature is lower during the hottest part of the day compared to when not having access to shade. Also the peak body temperature is lower (Fisher *et al.,* 2008). A study by Roman Ponce *et al.,* (1976) showed that unshaded cows had a rectal temperature of 39.4^{o}C compared to 38.9^{o}C for shaded. Likewise, the respiration rate for shaded cows versus unshaded was 54 and 82 breaths/min, respectively. A small difference was also shown by Tucker *et al.,* (2008) when comparing unshaded cows to cows with 99% of sun blockage. With 99 % of sun blockage the minimum body temperature was 37,7^{o} C and with no shade at all it was 37,9^{o}C. Finally, an old study by Seath and Miller (1946) showed that the cows preferred to enter shade when their body temperature was above 39^{o}C. This was an increase of 1^{o}C from their normal temperature when returned to pasture at 5:45 in the morning. Respiration rate had also increased from 63 to 71 breaths/min.

Milk production

Heat stress can cause a decline in milk production since the feed intake might decrease. When comparing cows with and without access to shade, the milk yield has been shown to be higher for shaded cows. However, the milk composition does not differ between shaded and unshaded cows. Daily milk yield also shows less variability when the cows have access to shade (Kendall, 2006).

High producing cows are more vulnerable to heat stress and the milk production declines more significantly than for low producing cows (Tapki and Sahin, 2006). The metabolic heat production increase since the feed intake and metabolic rate is higher of a high producing cow. In the early lactation, the high producing cows are very sensitive to heat stress, and if exposed to it, the milk production will decline. If the rectal temperature exceeds 39^{o}C, the milk yield declines significantly (Kadzere *et al.,* 2002). When comparing the behaviour of high and low producing cows in a hot climate, it has been shown that the high producing animals has a higher frequency of eating, drinking and standing, and a lower frequency of ruminating, locomotion and resting compared to low producing cows (Tapki and Sahin, 2006).

Fur colour

In a study by Tucker *et al*. (2008) it was shown that the coat colour might also influence the heat stress, since different amounts of heat is absorbed from the sun. White cows absorb less heat than black ones (West, 2003). The hair coat can vary from fine and glossy to thick and woolly and the insulation capability differs. A smooth, dense, light-coloured coat protects the best from solar radiation (Blackshaw and Blackshaw, 1994). When comparing Holstein cows and their preferences for shade, it showed that cows with a predominantly white coat did not seek shade as much as the predominantly black ones (Gaughan *et al.*, 1998).

Flies

Flies are normally attracted to the secretions from the lacrimal and sebaceous glands around the face and can be an exposed area. When exposed to many flies, the cattle might stop grazing and instead they stand with their head tight together for protection. They might also be more impatient and move around, seeking for wind. Tail swishing, head movements including ear flapping, can also reduce the infestation (Phillips, 1993).

Material and method

The practical part of the project was conducted at Kungsängen Research Centre in Uppsala between 6th of July and 16th of August 2009. All factors discussed in the literature review were not analyzed statistically since this thesis mainly focuses on the behaviour of the cow.

Animals

The study included 30 lactating dairy cows of the Swedish Red breed. The cows were between two and ten years of age and in their first to seventh lactation (mean 2.6). Their stage of lactation varied, and days in milk (DIM) at day one varied from 3 to 449. The mean milk production during the trial period was 25.31 l/cow.

The cows were kept in traditional tied up stalls when milked and otherwise they were held at pasture close to the stable, see Fig. 3. They were divided into two groups with fifteen cows in each group. At pasture, one group had access to shade in a tent (group 1) and the other group did not have access to shade (group 2). The tent was positioned in the middle of the enclosures, representing one corner of each enclosure. The total area of the tent was 78.5 m^2 and it was made of PVC. The cows had access to in average 4.6 m^2 each in the tent. The enclosures were in average 0.46 ha, meaning that the cows had access to 269 m^2, or there were 37 cows/ha. The cows were divided into the groups by visual control of the udder, where cows with sunburnt udders were selected to the group with access to shade. This was to protect these cows from the sun as much as possible. The age of the cows were also taken into consideration, so that the distribution was as equal as possible in both groups.

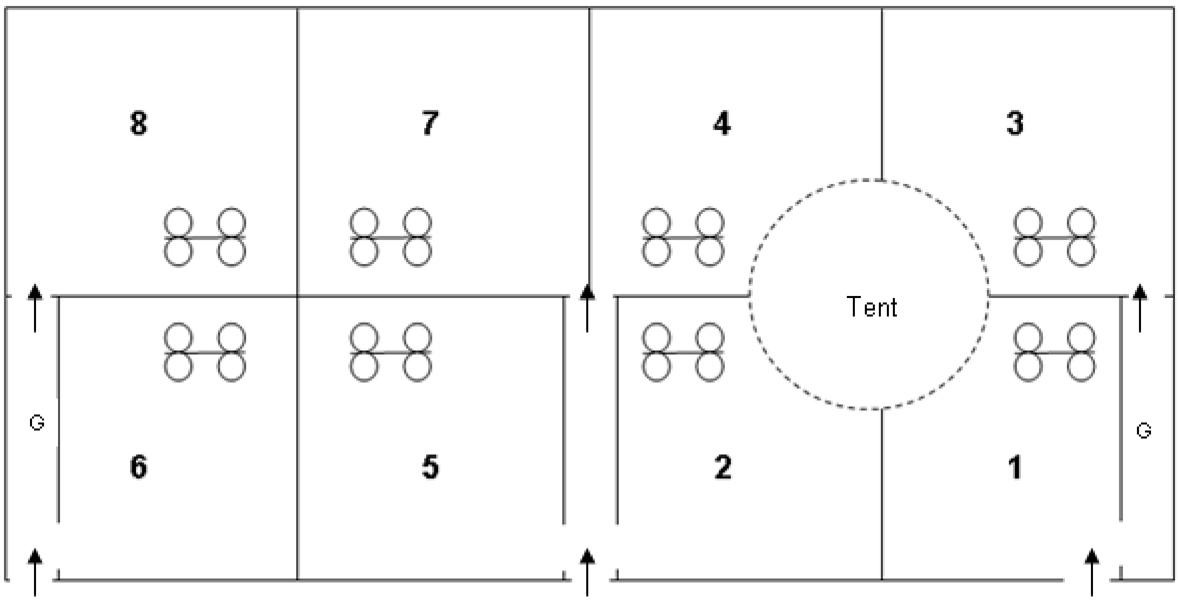

***Fig. 3**. Pasture layout. The cows with and without access to shade were circulating between enclosure nr 1-4 and 5-8, respectively. The cows had access to the entire tent and one quarter was opened, depending on what enclosure used. Water bows were positioned close to the tent and the cows entered the enclosures where marked with an arrow, and when held in enclosure 3,4,7 or 8, they were drifted through the gates named G.*

Meteorological data

The microclimate was measured at regular intervals of 10 minutes, using HOBO Pro Dataloggers (Onset Computer Corporation, Bourne, MA, USA). The dataloggers were placed at two different locations; one inside the tent and one outside. The climatic measures included the ambient temperature (C^o), the relative humidity (%) and the black globe temperature, BGT (C^o). THI was calculated from the ambient temperature and relative humidity.

Feeding of the cows and feeding samples

The cows were held on a pasture with mixed grass sward, and each group were circulating between four different enclosures. The time in each enclosure depended on the access of pasture, varying between three and six days. When milked, the cows were fed between 4 and 8 kg DM of ensilage, depending of the access of pasture, and concentrate according to their milk yield (Spörndly, 2003). Each time the cows were moved to a new enclosure, grass samples were taken to measure the quantity of pasture in dry matter content and energy as well as the grass components. There were no extra feed available inside the tent. Each group had access to four water bowls at pasture, and every day the total amount of consumed water for each group was measured. Calculations were made to determine the dry matter and energy intake, according to Spörndly (2003).

Behavioural observations

Behavioural observations were carried out at thirteen occasions, including four 24-h-periods. The observations were carried when the temperature exceeded at least 17^{o}C. The daytime observations began after milking in the morning at approximately 10 am, paused between 2:30 and 5 am and ended at 7 pm. During the 24-h-periods the observations continued until 6 am. The behaviour of all cows, and whether they were positioned in shade or not, were recorded in 10-minute intervals. Behaviours recorded are defined in Table 1. To be able to register the behaviour during night, the cows were marked with luminary numbers from 1 to 30. One single observer watched both groups at each occasion, but there were four different observers during the entire period.

Table 1. Ethogram, describing the different behaviours

Code and behaviour	**Description**
G = grazing	Standing with the head closer than 20 cm from the ground
D = drinking	The cows is standing and its muzzle is in contact with water
ST = standing	Standing or raising without displaying any other listed behaviour
L = lying	Lying down or on its way to lay down
LO = locomotion	Moving the legs, such as walking or running, without grazing
SO = social behaviours	Interaction between at least two cows, such as playing, fighting, mating
O = other behaviours	All other behaviours that can't be placed in previous categories
S = positioned in shade	At least one hoof is within the shadow from the tent
S + any of the other codes	The cow is expressing one of the listed behaviours with at least one hoof within the shadow from the tent

Milking and milk samples

All cows were milked twice a day, approximately at 7 am and 4 pm. The milk yield was measured at each milking. When the temperature outside was high, milk samples were taken to measure the components (fat, protein and lactose) and the somatic cell count of the milk. This was done in periods of three to six days, to see any possible long term changes.

Physiological parameters and flies

The cows' hair coat temperature was measured at four times during the entire period by using an IR thermometer. The temperature was measured at around 1:30 pm and at three different places on the cows back. The body temperature of the cows was also measured by using a rectal thermometer. This was done when the cows were milked in the morning and afternoon in connection to the behavioural observations.

The respiration rate was measured by visual counting of flank movements in 15 seconds and recorded as breaths per minute (bpm). Also, the number of flies on the head and udder region was visual counted and graded into a scale of low (0-10 flies), medium (11-20 flies) and plenty (20 flies and above). Both counting of flies and measuring respiration rate was done in connection with measuring the cows' coat temperature.

Statistical analyses

Data were analyzed using PROC GENMOD procedures in SAS (SAS institute, 1999). A p-value of <0.05 was considered statistically significant. Since data were not normally distributed, a binomial distribution was used.

The statistical analyses for the behavioural observations were divided into four parts:

- Daytime for the group with access to shade
- Daytime for both groups
- 24-hour period for the group with access to shade
- 24-hour period for both groups

The model used was:

$Y_{ijklmnopq}$ = μ + $(\text{group})_i$ + $(\text{THI})_j$ + $(\text{period})_k$ + $(\text{lactation number})_l$ + $(\text{enclosure})_m$ + $(\text{days in enclosure})_n$ + $(\text{milk yield})_o$ + $(\text{milk yield+1})_p$ + $(\text{milk yield+2})_q$ + $(\text{period * THI})_{jk}$ + $(\text{group * THI})_{ij}$ + $\varepsilon_{ijklmnopq}$

where

μ = mean value of all the observations

Group = group with or without access to shade

THI = temperature-humidity index

Period = Period 1: 9:00-14:30, Period 2: 17:30-22:00 during 24 h-period and 17:30-19:00 during day time, Period 3: 22:00-06:00

Lactation number = number of lactation

Enclosure = what enclosure the cows were kept in (1-4)

Days in enclosure = number of days the cows have been in the same enclosure (1-5)

Milk yield = total milk yield the same day as behavioural observations

Milk yield+1 = total milk yield the day after behavioural observations

Milk yield+2 = total milk yield two days after behavioural observations

ε = random error

The fixed variables were cow number, group, lactation number, period, enclosure and days in enclosure. The model was simplified, depending on significant and not significant variables.

SAS were not able to converge the complete model for all the analyses and therefore some variables were eliminated. In the group with access to shade the model for drinking, social, and other behaviour were simplified, both for daytime observations and during the 24-h-period. Also, the model for all the behaviours in shade had to be simplified. Least squares means were calculated for all the significant variables, except for those who did not converge.

The analysis of the continuous variables was made in terms of odds ratios. Odds ratio can be explained by the ratio of the odds of an event that occurs in one group to the odds of it occurring in another group. If the probabilities in each group is p_1 and p_2, respectively, the odds ratio is: $\frac{p_1/(1-p_1)}{p_2/(1-p_2)}$. In logistic regression, used for binomial regressions, the formula $e^b = \frac{p_1/(1-p_1)}{p_2/(1-p_2)}$ gives the odds ratio. b is the coefficient/parameter, in this case THI. An odds ratio of 1 indicates that the event is equally likely to occur in both groups. An odds ratio above 1 indicates that the event is more likely to occur in the first group. An odds ratio less than 1 indicates that the event is more likely to occur in the second group. These odds ratios where then compared for each significant behaviour.

In the SAS procedure, type 3 tests were used to achieve the score statistics. Thus, there was no hierarchy within the model. However, when analyzing least squares means, type 2 tests is the standard in SAS tests and were used, and therefore the significance shows various results. Score statistics and type 3 was stated to the leading analyze concerning the significance.

Results

Meteorological data

Meteorological data showing temperature (C^o), relative humidity (%) and THI from the non-shaded area is summarized in Table 2. The average data during the entire period is also shown.

Table 2. Meteorological data at 13 days during the observation period and over 24 h. Observations from 9 am to 7 pm were performed all days and 24 hours observations on day 1, 2, 10 and 13

		Temperature (C^o)			Relative humidity (%)			THI		
Day	**Date**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**
1	2009-07-12	17.34	11.90	23.62	80.11	56.21	97.28	62.21	53.53	70.70
2	2009-07-15	20.42	9.21	27.58	67.74	41.14	96.41	65.74	48.83	74.20
3	2009-07-16	20.27	12.29	25.28	71.75	48.39	96.40	66.33	54.25	72.26
4	2009-07-17	21.17	14.67	28.69	66.64	39.01	93.39	67.22	58.39	75.25
5	2009-07-18	20.39	11.05	27.41	67.25	40.92	96.83	65.83	52.05	73.87
6	2009-07-20	18.17	14.27	22.23	74.95	47.31	96.06	63.43	57.69	68.27
7	2009-07-22	17.77	13.11	25.55	76.53	49.66	93.66	62.64	55.73	72.65
8	2009-07-23	19.15	14.70	24.07	83.48	67.44	94.69	65.56	58.43	72.23
9	2009-08-05	20.90	10.54	31.66	71.10	33.59	96.66	66.26	51.18	77.98
10	2009-08-06	21.35	11.32	33.08	70.59	34.50	96.73	67.24	52.51	79.59
11	2009-08-07	20.08	11.73	29.67	77.41	46.34	97.18	66.04	53.23	77.99
12	2009-08-08	20.34	10.49	29.57	69.29	38.69	96.88	65.48	51.01	76.84
13	2009-08-09	19.85	9.90	28.27	67.36	39.87	96.55	64.69	50.01	74.88
Average		19.78	11.94	27.44	72.63	44.85	96.05	65.28	53.60	74.36

Shade use and THI

The cows started using the shade structure at the second observation day (2009-07-15) and all cows used the tent to some extent during the entire period. The cows started using the tent when THI was 66.9 and during the entire period, the cows used the tent in average 14.5 % of the time per day between 9 am to 7 pm.

During daytime-observations, the cows were positioned in shade about 5 % of the time when THI was 69 and lower. As THI increased, the cows used the shade to a greater extent (Fig. 4). When THI reached 77 and above, the proportion of time spent in shade was almost 20 %. When the cows were positioned in shade, the most common behaviour was standing (Fig. 5.)

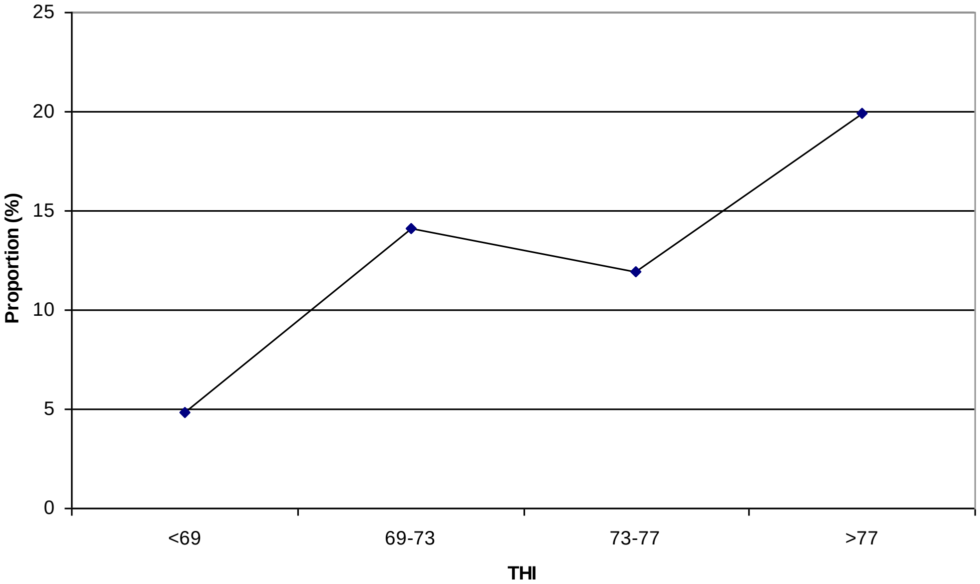

Fig. 4. *Proportion of cows positioned in shade at various THI-values.*

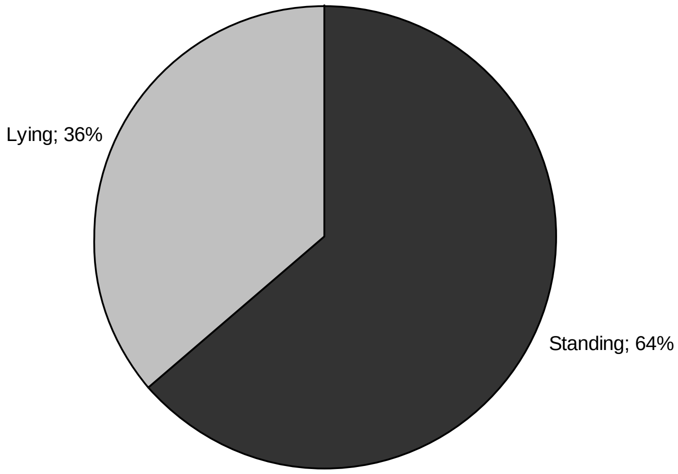

Fig. 5. *Distribution of standing and lying behaviour of cows when positioned in shade. Locomotion, drinking, social and other behaviour are included in "standing".*

Table 3 shows the effects on the behaviours when THI, or THI in interaction with period or group, increases with 1. Interactions with group 1 are compared to group 2, and interactions with period 1 is compared to period 2 during day time observations, and to period 2 and 3 during the 24-hours observations. For example, when THI increases with 1 for both groups during day time, grazing behaviour decreased ($p = 0.002$), and when THI increases with 1, grazing behaviour increased in group 1 and period 1 compared to group 2 and period 2 ($p<0.0001$ and $p = 0.0001$, respectively).

As seen in Table 3, when comparing behaviours in group 1 at daytime, "all shade behaviours" increases as THI increases with 1 ($p<0.01$). Divided into specific behaviours, "standing in shade" increases (p<0.05) along with THI, while lying and locomotion in shade (p<0.05 and p<0.01, respectively) decreases. The amount of both "standing in shade" and "all shade behaviours" decreased during period 1 compared to period 2, in interaction with THI (p<0.01 and p<0.01, respectively). When comparing shade behaviours during a 24-h period, "all shade behaviours" and "standing in shade" are decreasing (p<0.001 and p<0.001, respectively) as THI increases.

Table 3. Odds rations for THI and THI in interaction with group and period. An increase of 1 of the parameter gives a decrease/increase of the behaviour. Odds rations below 1 gives a decrease of the behaviour and odds rations over 1 gives an increase. Only the significant behaviours are shown in the table.

Group	Behaviour	Parameter	Odds ration	P-value
Both groups, daytime	Grazing	THI	0.81	0,0020
		THI * period 1	1.26	<0,0001
		THI * group 1	1.11	0,0001
	Standing	THI	1.24	0,0430
		THI * period 1	0.68	<0,0001
	Lying	THI	1.07	0,0021
		THI * group 1	0.90	0,0483
	Locomotion	THI	1.25	0,0017
		THI * period 1	0.92	0,0386
	Social behaviour	THI	1.08	0,0046
Both groups, 24-h	Grazing	THI	0.89	0.0002
		THI * period 1	1.16	<0,0001
		THI * period 2	0.98	<0,0001
	Standing	THI	0.80	<0,0001
		THI * period 1	1.05	<0,0001
		THI * period 2	1.46	<0,0001
	Lying	THI	1.24	<0,0001
		THI * period 1	0.86	0,0004
		THI * period 2	0.91	0,0004
	Locomotion	THI	2.83	0,0351
		THI * period 1	0.37	0,0435
		THI * period 2	0.36	0,0435
Group 1, daytime	Grazing	THI * period 1	1.31	0,0004
	Standing	THI	1.15	0,0034
		THI * period 1	0.87	0,0111
	Lying	THI * period 1	1.13	0,0098
	Standing in shade	THI	1.01	0,0143
		THI * period 1	0.67	0,0019
	Lying in shade	THI	0.78	0,0015
	Locomotion in shade	THI	0.83	0,0333
	All behaviours in shade	THI	1.05	0,0050
		THI * period 1	0.60	0,0020
Group 1, 24-h	Standing	THI	1.04	0,0344
		THI * period 1	1.20	0,0035
		THI * period 2	0.98	0,0035
	Grazing	THI * period 1	1.35	0,0030
		THI * period 2	1.37	0,0030
	Lying	THI	1.31	0,0008
		THI * period 1	0.84	0,0044
		THI * period 2	0.82	0,0044
	Standing in shade	THI	0.72	0,0006
	All behaviours in shade	THI	0.71	0,0008

According to Table 3, standing behaviour increased as THI increased for both groups at daytime and during a 24-h period, and for group 1 during a 24-h period (p<0,05; p<0,001 and p<0,05, respectively). Grazing behaviour decreased in both groups at daytime and 24-h period (p<0,001 and p<0,001, respectively). Instead, locomotion behaviour increased in the same analyses (p<0,01 and p<0,05, respectively). Lying behaviour increased as THI increased in all the analyses.

Fig. 6, 7, 8 and 9 shows the diurnal activities at the coldest (THI-max = 70.5, 2009-07-12) and warmest (THI-max = 79.6, 2009-08-06) day in group 1 and 2 during the entire period. When comparing group 1 and 2 during the colder day (Fig. 6 and 7) it seems like there was a higher activity of grazing at 6 pm in group 2. Instead, the cows were standing more of the time in group 1. Also, group 2 had a higher activity of lying behaviour between 11 pm and 4 am, and group 1 seems to graze to a higher extent during the night.

When comparing group 1 and 2 during the warmer day (Fig. 8 and 9) it seems to be a higher activity of standing in group 1 at 12 am. In group 2 on the other hand, the cows are grazing to a higher extent. Also, it seems like the cows were lying down more in group 2 at 2 pm. In group 1 there was a higher activity of grazing at the same time.

Finally, when comparing both of the groups at the warmer and colder day (Fig. 6, 7, 8, and 9), a higher activity of grazing was seen during the night at the warmer day. Instead, the grazing activity was lower at around 2 pm. The cows also seems to stand up more in period 1 during the warmer day.

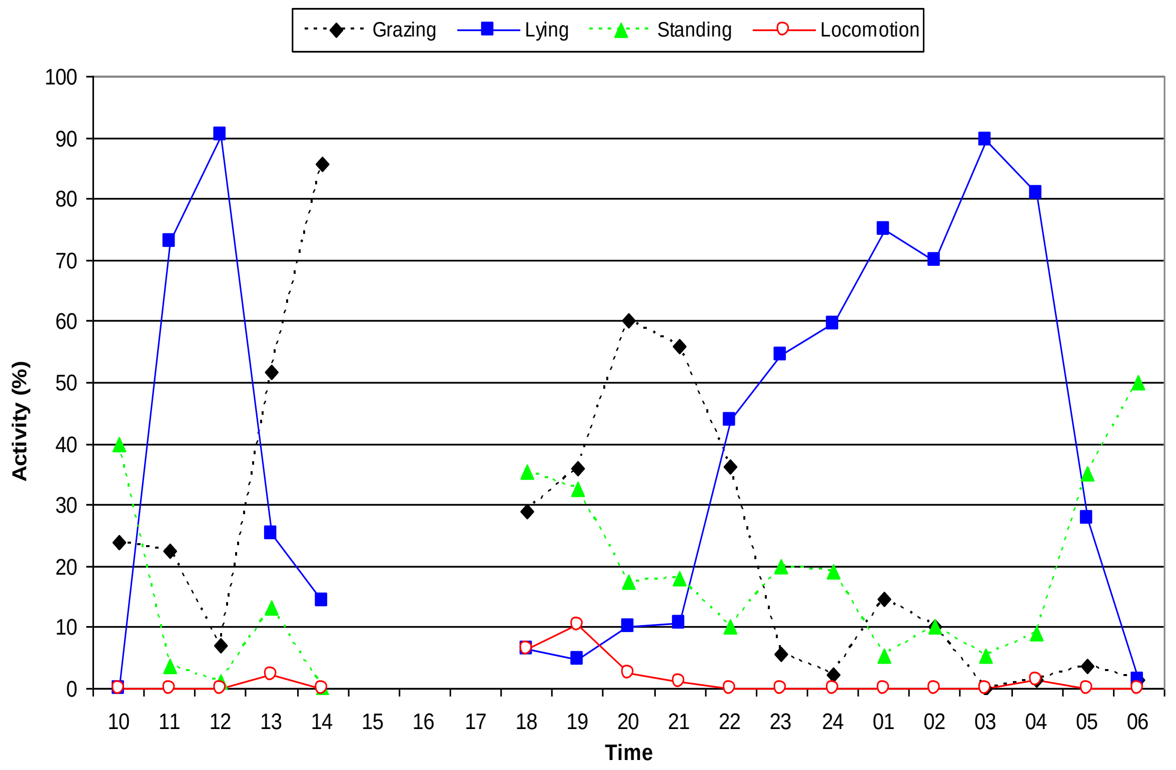

Fig. 6. Diurnal activities in group 1 (cows with access to shade) during a 24-h period with a THI-maximum of 70.5. Drinking, social and other behaviour are included in "standing". The cows were milked between 14 and 18. The activity is calculated by dividing the number of observations of a certain behaviour to the total number of observations.

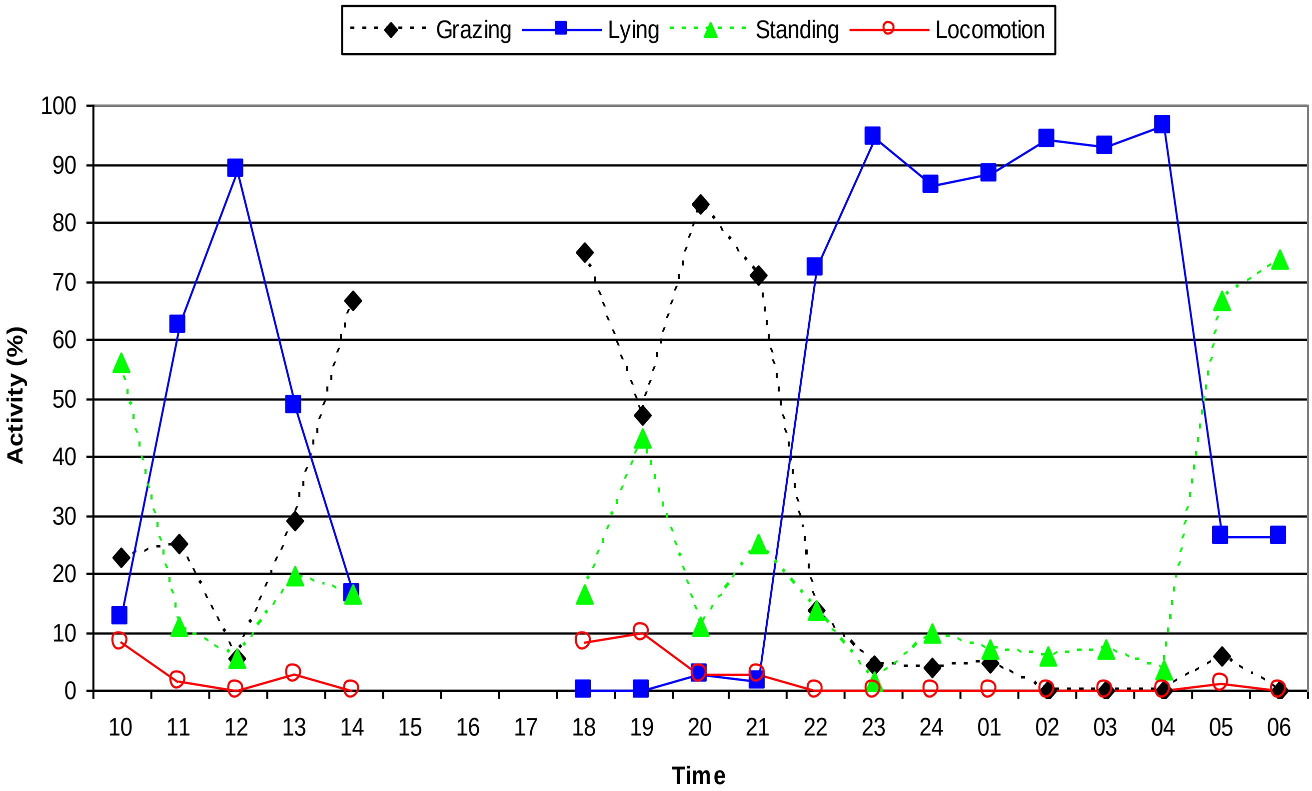

Fig. 7. *Diurnal activities in group 2 (group without access to shade) during a 24-h period with a THI-maximum of 70.5. Drinking, social and other behaviour are included in "standing". The cows were milked between 14 and 18. The activity is calculated by dividing the number of observations of a certain behaviour to the total number of observations.*

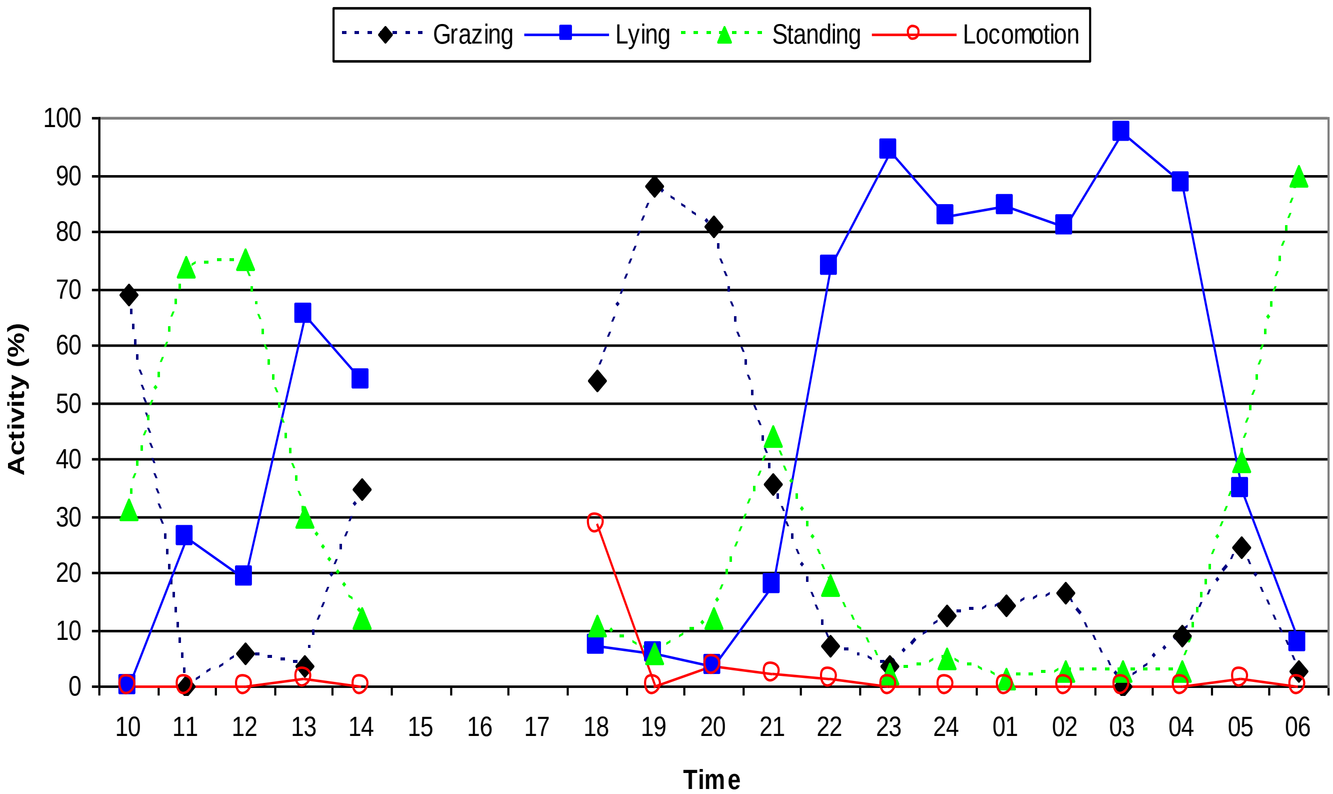

Fig. 8. *Diurnal activities in group 1 (cows with access to shade) during a 24-h period with a THI-maximum of 79.6. Drinking, social and other behaviour are included in "standing". The cows were milked between 14 and 18. The activity is calculated by dividing the number of observations of a certain behaviour to the total number of observations.*

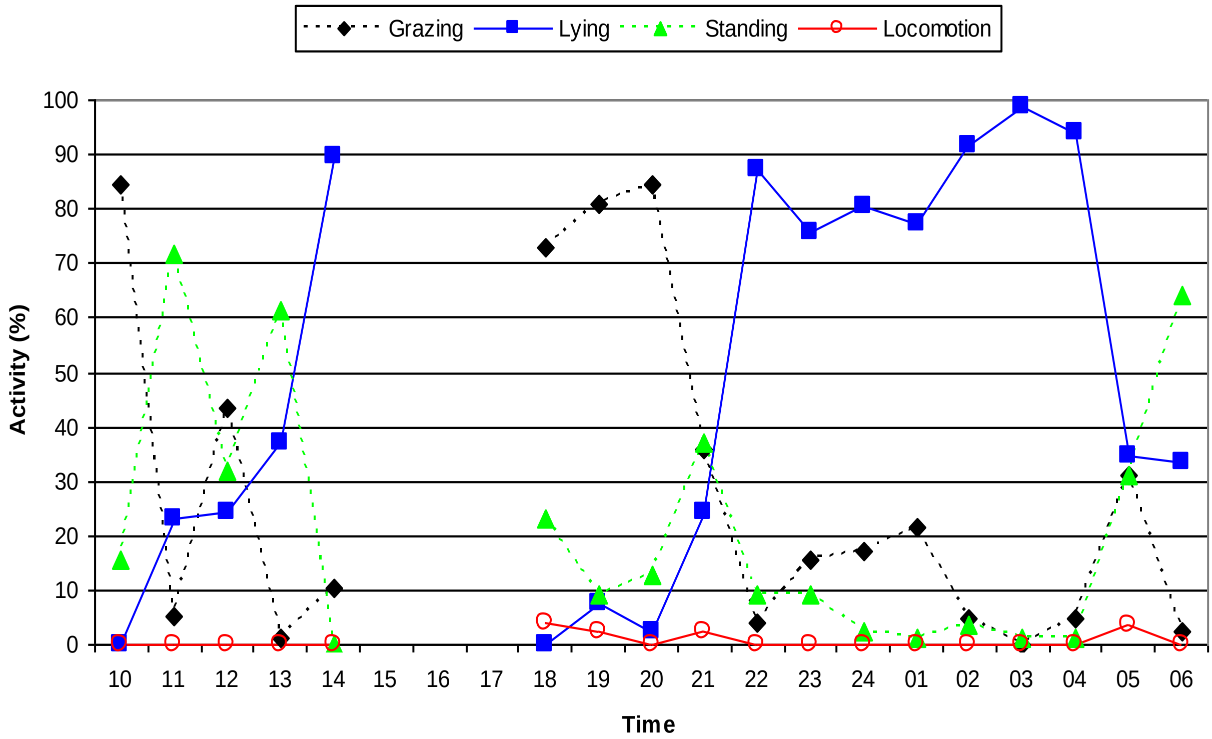

Fig. 9. *Diurnal activities in group 2 (cows without access to shade) during a 24-h period with a THI-maximum of 79.6. Drinking, social and other behaviour are included in "standing". The cows were milked between 14 and 18. The activity is calculated by dividing the number of observations of a certain behaviour to the total number of observations.*

The importance and effects of period, group and enclosure

Period

There was a significant effect between the periods during both daytime and 24-h periods. Figure 8 and 9 shows the proportion of the significant behaviours at daytime and during the 24-h-periods. As seen in Fig. 8. the cows grazed to a greater extent in period 2 than in period 1 ($p<0.001$) during daytime. The cows also had a higher frequency of standing during period 1 than during period 2 ($p<0.001$), and locomotion was more common in period 2 than in period 1 ($p<0.05$). During the 24-h period, grazing was more frequent in period 2 than period 1 and 3 ($p<0.001$). Also, the cows lied down to a higher extent in period 3 than period 1 and 2 ($p<0.001$).

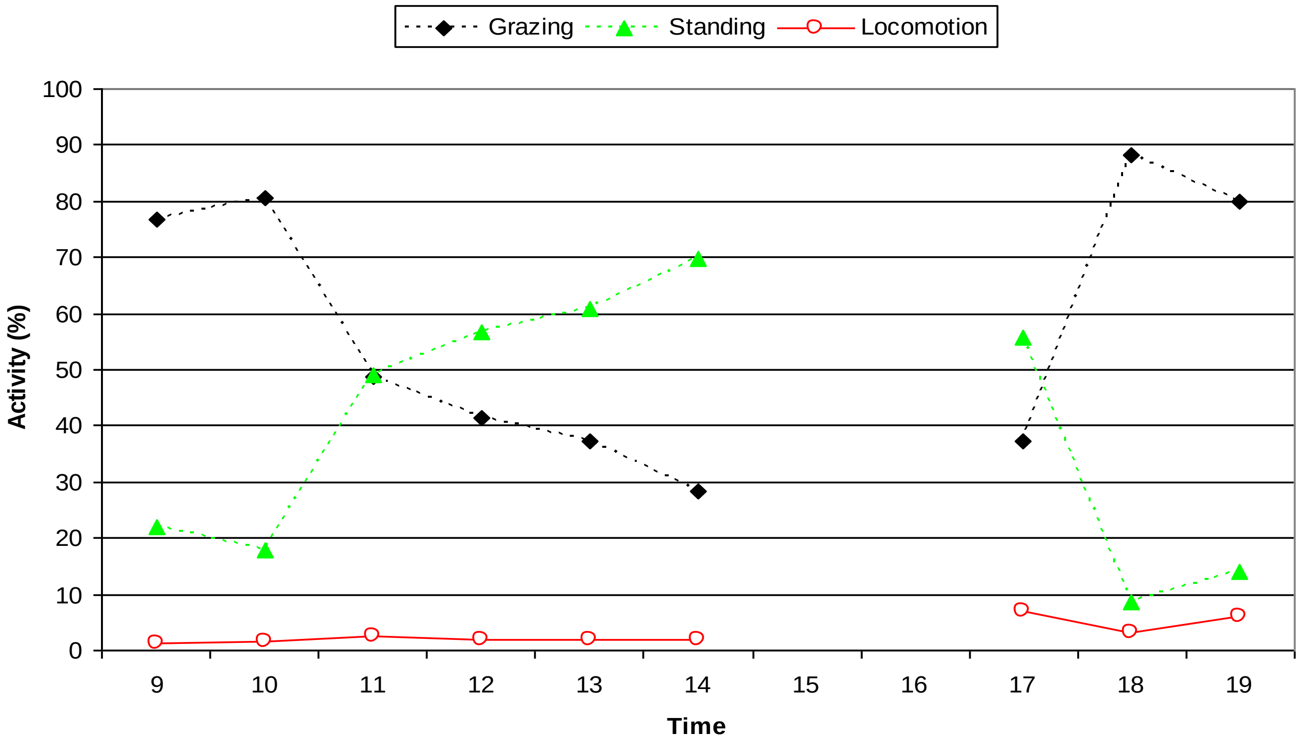

Fig. 8. *Diurnal activities for group 1 and 2 (group with and without access to shade, respectively) at daytime during the entire trial. Period 1 and 2 covers from 9 am to 14 pm, and 17 pm to 19 pm, respectively. Only behaviours that are significant are shown in the figure. The activity is calculated by dividing the number of observations of a certain behaviour to the total number of observations.*

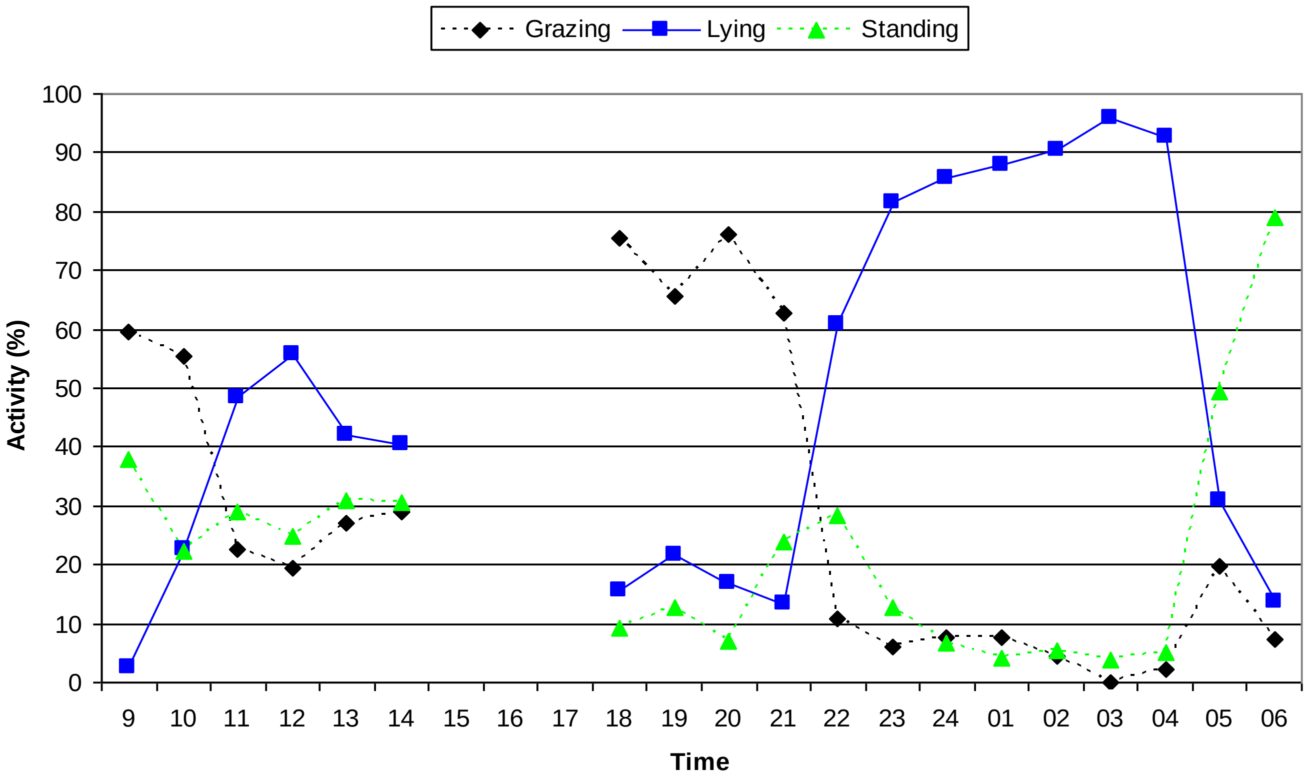

Fig. 9. *Diurnal activities for group 1 and 2 (group with and without access to shade, respectively) at the 24-h-periods during the entire trial. Period 1,2 and 3 covers from 9 am to 14 pm, 17 pm to 10 pm, and 10 pm to 6 am, respectively. Only behaviours that are significant are shown in the figure. The activity is calculated by dividing the number of observations of a certain behaviour to the total number of observations.*

Group

Whether the cows were placed in group 1 or 2 had a significant effect on grazing and lying behaviour at daytime. The cows in group 2 were grazing to a higher extent than in group 1 (43 %, CI: 39-48 % vs. 38 %, CI: 34-42 %; p<0.001). Also, group 2 had a higher probability of lying than group 1 (33 %, CI: 31-35 % vs. 33 %, CI: 30-37 %; p<0.05).

Enclosure

There was also a significant effect on the behaviour depending on which enclosure the cows were kept in (Table 4 and 5). During the 24-hour observations, the cows were by chance only kept in enclosure no 2 and 3.

Table 4. The probability and confidence interval (CI) of a certain behaviour to occur in group 1 and 2 (group with and without access to shade, respectively), depending on what enclosure (1-4)[a] the cows were kept in during daytime. Only the behaviours with a significant difference are shown in the table.

		1 (5)		2 (6)		3 (7)		4 (8)		
		Prob (%)	CI (%)	Prob (%)	CI (%)	Prob (%)	CI (%)	Prob (%)	CI (%)	P-value
Group 1	Grazing	33.1^{a}	27.9 - 38.7	40.9^{b}	33.3 - 49.0	46.8^{b}	43.6 - 49.9	32.4^{a}	29.4 - 35.6	0,0001
	Standing	$13.0^{a,b,c,d}$	9.9 - 17.0	10.9^{b}	8.4 - 13.9	$14.5^{c,d}$	11.6 - 18.0	16.0^{d}	13.5 - 18.8	0,0124
	Lying	43.4^{a}	38.2 - 48.6	24.9^{b}	20.8 - 29.5	$28.9^{b,c}$	25.8 - 32.2	36.1^{d}	32.8 - 39.7	0,0029
	Locomotion	0.6^{c}	0.2 - 1.9	8.3^{b}	4.3 - 15.5	$1.6^{a,b}$	1.1 - 2.3	0.4^{c}	0.2 - 0.8	0,0025
Group 2	Grazing	35.9^{a}	29.9 - 42.4	$47.0^{b,d}$	37.2 - 57.1	49.3^{b}	45.1 - 53.5	$41.1^{a,c,d}$	35.9 - 46.6	0,0001
	Standing	$11.2^{a,b,c}$	8.6 - 14.5	14.4^{b}	9.9 - 20.4	9.8^{c}	8.0 - 11.9	12.8^{b}	10.7 - 15.4	0,0124
	Lying	47.8^{a}	42.0 - 53.6	23.0^{b}	19.1 - 29.6	$29.8^{c,d}$	26.7 - 33.1	32.9^{d}	27.6 - 38.7	0,0029
	Locomotion	0.3^{a}	0.1 - 0.6	$5.3^{b,c}$	1.8 - 14.3	1.7^{c}	1.2 - 2.6	0.4^{a}	0.2 - 0.8	0,0025

Note: Different superscript letters shows that there are a significant difference (p<0.05) between the probabilities.
a: Group 1 were rotating between four different enclosures (1-4), and group 2 were rotating between enclosure no 5-8.

Table 5. The probability and confidence interval (CI) of a certain behaviour to occur in group 1 and 2, depending on what enclosure (2-3)[a] the cows were kept in during a 24-hour period. Only the behaviours with a significant difference are shown in the table.

		2 (6)		3 (7)		
		Prob (%)	CI (%)	Prob (%)	CI (%)	P-value
Group 1	Grazing	34.5^{a}	27.9 - 41.7	28.3^{a}	23.5 - 33.7	0,0147
	Standing	23.1^{a}	18.8 - 28.1	20.6^{a}	16.9 - 24.9	0,0313
	Lying	30.8^{a}	26.6 - 35.2	41.9^{b}	37.3 - 46.6	0,0106
Group 2	Grazing	29.5^{a}	25.4 - 33.9	35.0^{b}	30.0 - 40.4	0,0147
	Standing	21.8^{a}	18.3 - 25.7	15.1^{b}	11.8 - 19.0	0,0313
	Lying	38.8^{a}	33.1 - 44.8	42.0^{a}	37.9 - 46.3	0,0106

Note: Different superscript letters shows that there are a significant difference (p<0.05) between the probabilities.
a: Group 1 were inside enclosure no 2 and 3 and group 2 was inside enclosure no 6 and 7, respectively, during the 24-h observations.

Feeding and pasture availability

The calculations of available pasture showed that there was a lack of energy supply. In average, the cows require 70 MJ of energy content each day from the pasture, and there was only about 60 MJ available. Water amount consumed at pasture was in average 34.6 l/day for the cows with access to shade and 30.0 l/day for cows without access to shade.

The amount of pasture available was graded in a scale of 1-5 and tested to see any possible effects on the behaviour of the cows (Table 6). A value of 1 represents the first day in an enclosure, and number 5 represents the 5th day in the same enclosure. It was only possible to analyze the behaviours at daytime since the data for 24-hour periods did not converge in SAS.

Table 6. The probability and confidence interval (CI) of a certain behaviour to occur at daytime in group 1 and 2 (group with and without access to shade, respectively), and group 1 (group with access to shade), depending on how many days the cows has been in the same enclosure (1-5)[a]. Only the behaviours with a significant difference are shown in the table.

		1		2		3		4		5		
		Prob (%)	CI (%)	Prob (%)	CI (%)	Prob (%)	CI (%)	Prob (%)	CI (%)	Prob (%)	CI (%)	P-value
Daytime	Grazing	38.8[a]	35.2 - 42.6	45.1[b]	41.1 - 49.1	34.0[c]	30.6 - 37.5	48.0[b]	43.1 - 52.9	38.0[a,c]	33.5 - 45.7	0,0002
	Standing	21.0[a]	17.1 - 24.3	8.9[b]	7.1 - 11.1	14.1[c]	12.1 - 16.3	9.3[b]	7.3 - 11.7	13.4[c]	11.1- 16.1	<0.0001
	Lying	21.8[a]	19.6 - 24.1	34.7[b]	31.8 - 37.8	39.7[c]	36.6 - 42.9	35.8[b,c,d]	32.6 - 39.1	34.9[b,c,d]	30.2 - 39.9	<0.0001
	Locomotion	2.8[a]	1.8 - 4.4	3.0[a]	2.1 - 4.1	0.4[b]	0.2 - 0.8	1.4[c]	0.8 - 2.8	0.4[b,d]	0.2 - 1.0	0,0037
Daytime, group 1	Grazing	34.5[a]	30.6 - 38.6	43.9[b]	40.0 - 47.8	33.9[a]	28.4 - 38.3	53.5[c]	47.1 - 59.8	40.4[a,b]	34.4 - 46.8	0,0106
	Standing	6.1[a]	4.5 - 8.4	2.7[b]	1.7 - 4.2	16.6[c]	13.5 - 20.2	6.7[a]	4.9 - 8.9	24.0[d]	17.0 - 32.9	0,0117
	Lying	14.4[a]	11.6 - 17.8	26.6[b,e]	23.7 - 29.8	36.2[c]	30.7 - 42.1	24.6[b,d]	20.1 - 29.8	37.0[c,d,e]	27.7 - 47.4	0,0122
	Standing in shade	12.3[a]	7.4 - 17.5	4.7[b]	3.0 - 7.4	4.5[b,c]	2.7 - 7.3	3.8[b,c]	2.2 - 6.3	4.6[b,c]	2.6 - 8.1	0,0095
	Shade, total	19.8[a]	14.7 - 26.2	7.3[b]	4.8 - 10.9	8.0[b,c]	5.3 - 11.8	9.2[b,c]	5.8 - 14.4	3.7[d]	1.9 - 6.5	0,0103

Note: Different superscript letters shows that there are a significant difference ($p<0.05$) between the probabilities.
a: A value of 1 represents one day in the same enclosure, a value of 2 represents two days in the same enclosure, etc., until five days in the same enclosure.

Discussion

The cows increased their shade use as THI increased. These findings are consistent with other studies (Schütz *et al.*, 2008; Gaughan *et al.*, 1998). There was a fall in shade use at THI-values between 73 and 77. This was the case for five days (2009-07-15, 2009-07-17, 2009-07-18, 2009-08-08 and 2009-08-09). The average relative humidity for these days did not exceed 70 % and since heat stress is connected to a high relative humidity (West *et al.*, 2003) this can be a possible explanation to why the cows didn't use the shade as much as expected. The most common behavior under shade was standing and this was similar to the study by Tucker *et al.*, (2008).

Cows used the shade structure in average 14.5 % of the day between 9 am to 7 pm. In a study by Schütz *et al.*, (2009) the same amount was 29.8 %. The average THI value in that study was 72.6, and in the present study 65.3. Therefore it makes sense that the cows used the tent to a lower extent in this study. According to SMHI, the temperature in July was normal, however, the precipitation was higher than the average amount. In August, the temperature was higher and the precipitation a bit higher than expected. In average, the temperatures was not as high and the precipitation was not as low as desired and of course this can have an impact on why the cows didn't use the shade as much as expected.

The cows spent less time grazing as weather became warmer and THI increased, which is in agreement with earlier research (Tucker *et al.*, 2008). The decrease in grazing behaviour when THI increased can probably be explained by the fact that the cows might not be able to dissipate the heat associated with feed digestion (Marcillac-Embertson *et al.*, 2009; Kadzere *et al.*, 2001). Cows increased their standing behaviour as THI increased, which might be explained by convection between the cow and the ground. If the temperature of the ground is higher than that of the cow, the heat will be transferred to the cow. When standing, the exposed area to the ground is decreased compared to when the cows is lying and thereby the convection is minimized (Kendall *et al.*, 2006). However, the lying behaviour also increased as THI increased and probably the temperature of the ground was not that high. Most likely, the temperature of the ground was higher outside the tent than inside, and perhaps the lying behaviour was increased inside the tent and the standing behaviour was increased outside the tent. Also, cows chose to move around more when exposed to high temperatures, this might be due to discomfort and restlessness (Schütz, 2008).

When comparing group 1 and 2, and a higher and a lower THI, the grazing activity differed. During a warm day, grazing behaviour decreased at around 2 pm and instead increased during the night. This is similar to other studies (Kendall *et al.*, 2006) and probably due to the temperature and THI. At noon, the temperature and THI was at the highest and the cows might avoid eating in order to decrease the metabolic heat production. However, to compensate the grazing and energy supply, they eat during the night when the temperatures are lower. As earlier mentioned, this study indicates that cows prefer to stand up at higher temperatures. When comparing group 1 and group 2 during the warmer day, cows in group 2 grazed to a higher extent around noon, and cows in group 1 was standing. Probably, the cows in group 1 were standing inside the tent where no pasture was available. There is a high activity for standing around 6 am, which might be explained by the fact that the cows were used to getting milked at that time and stood up waiting for the keeper to come and bring them in for milking.

It was seen in the present study that cows grazed to a greater extent in period 2, and that is probably explained by the length of the periods. Period 2 only covers the interval 17-19 (5 pm to 7 pm), and period 1 covers 9-14 (9 am to 2 pm). When cows were let out at pasture after milking, the grazing activity was always high, but with data from the 24-h observations it was shown that the activity normally declines at about 8-9 pm. Cows also had a higher activity for locomotion in period 2. At first, they moved around and then settled down after a while. The cows lied down to the highest extent in period 3, similar to (Fisher *et al.,* 2008).

The cows grazed to a less extent than expected during this experiment. There was a minor lack of pasture, which might be the reason for the low grazing behaviour. However, according to Spörndly (2003) the energy content was normal to the time of the summer (10.5 MJ, normal: 10.5-10.8). The animals were also fed silage inside when milked, and the amount was corrected by if the cows showed any hunger symptoms by making a lot of noise and emptying the feeding troughs completely. We didn't want the cows to decrease in milk yield because of lack of feed. Another possible explanation is that the cows preferred to be in shade during the day rather than being out in the sun grazing.

According to Jordbruksverket (2001), the recommended stocking density at pasture in May-June is 4-6 cows/ha, and then it declines during the summer to 2-3 cows/ha. The enclosures in the present study were in average 0.46 ha (min: 0.40 ha, max: 0.53). That means that in average, the cows had access to 269 $m^{2,}$ or there were 37 cows/ha. However, since the cows are moved every 3rd to 5th day, the stocking density is probably not that high. Even though the cows were moved that often, it might be an indication that they did not have as much space as desired. The recommended space inside the tent is 4.2 m^2/cow (Buffington *et al.*, (1983), which is within the boundaries for the present study.

In the beginning of the experiment, the cows were habituated to the shade by feeding a small amount of silage inside the tent. Also, the cows were drifted through the tent in the beginning to introduce and habituate them. This might have influenced the cows' behaviour and preferences for shade use. The tent was also placed in such a way that the enclosure had an effect on the cows' behaviour. The cows were easily approaching the main gate which they were drifted through when going in and out from milking. Therefore, in some of the enclosures where the tent was far away from the main gate, cows seemed to use the tent to a less extent. This was most obvious in the beginning of the experiment.

There were no significant effect between THI and drinking, as could have been expected. This might have several reasons. There were few observations of drinking compared to other behaviours, so SAS could not converge the data and the model was very simplified. Also, the cows drank a lot of water inside the barn when milked and there was often a queue to the water bowls at pasture.

As mentioned in the statistical method part in the present study, there were some problems concerning the statistical analyses. The model was very simplified in several of the analyses and therefore it is not certain that the significant results are correct. The results and data from this experiment do, however, give an indication of how the cows react to shade and heat stress.

Conclusions

In conclusion, dairy cows in Sweden prefer to use shade if available when the temperature and relative humidity is high. Cows change their diurnal rhythm and compensate for a lower grazing frequency during the day by grazing more at night during days with a high THI. Instead of grazing, cows stand up and move around more when THI is increased. They also lie down to a higher extent. Their most common behaviour inside the tent is standing.

Cows without access to shade lie down and graze to a higher extent than cows with access to shade. Cows lie down to the highest extent between 10 pm and 6 am and they graze at the most between 5 pm and 10 pm.

Even though there is an indication that cows prefer using shade if available, more research is needed to see if the well-being is reduced by the absence of shade.

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