Sveriges lantbruksuniversitet
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Swedish University of Agricultural Sciences
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Exercise pasture compared with production pasture in a part time grazing system with automatic milking

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Examensarbete / SLU, Institutionen för husdjurens utfodring och vård, **415**

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Rastbete jämfört med produktionsbete i ett system med deltidsbete och automatisk mjölkning

Oleksiy Guzhva

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Introduction

Economic conditions in the milk industry constantly challenge farmers to find the solutions for being profitable and competitive at the same time. Grazed grass was always reported as a cheap feed source and indispensable element of many milk production systems worldwide. During recent years, increased emphasis towards automatic milking systems (AMS) has resulted in the slightly decreasing number of farms using grazing as one of the main sources of obtained nutrients for their animals (Jacobs and Siegford, 2012).

On one hand, Swedish law requires all the female cattle older than six months to be on pasture during the grazing season (SFS 1988:539, §10). Lack of access to pasture could be considered as a threat to welfare and health of dairy cows because of documented positive effects of grazing such as improved leg health, lower prevalence of mastitis and a decrease of stereotypies and aggression in the herd (Kilgour, 2012).

On the other hand a lot of farmers state reduced consistency in feed intake from day to day in pasture-based systems compared to the confinement systems. Planning the supplement feeding could take more time and lead to additional economic losses. Among the commonly stated problems are increased labor costs for fetching cows from the field and decreased number of visits to the milking unit per cow per day (Jago *et al.,* 2007; Davis *et al.,* 2008).

Part-time pasture-based systems could be defined as mixed-feed systems where part of the obtained forage in the ration comes from pasture, while the major part is stored feed. Referring to Dartt *et al.* (1999), part-time pasture-based system is the one where at least 25% of the all nutrient requirements are fulfilled by pasture and where animals are grazing for at least four months during the season. This definition could be slightly adapted to the conditions of the Swedish summer and vary in different parts of the country.

There are two terms closely related to the definition of part-time grazing systems – exercise and production pastures respectively. Exercise pasture is usually giving cows a small grazing area which just gives an animal opportunity to be outside without fulfilling its metabolic needs in a full range. Sward quantity on the exercise pasture is usually lower compared to the production area due to continuous grazing pressure and absence of any sward renovation procedures like additional fertilization or cutting. Quality may also be lower due to a large number of animals per land unit that leads to fouling and due to an over grazed sward. However, quality may in some cases be high as the sward is kept in a vegetative phase due to the high stocking rate (Campbell-Arvai, 2009).

In spite of a common statement that a combination of restricted grazing and AMS systems could negatively affect general farm economy due to a decreased milking frequency and increased costs for labor, some researchers shows contradictory results. Jago *et al.* (2007) in their experiment demonstrated that the general number of visits to the milking unit depends mostly on the cow-traffic model applied to the situation. Ketelaar-de Lauwere and Ipema (2000) and Wiktorsson and Spörndly (2002) showed a direct connection between walking distances to the pasture and the sward height. Through the manipulation with these parameters, number of visits to milking unit and time spent in-/ outdoors could be changed.

Some researchers state that the cows' willingness to explore and acquire new pasture every day can be used to achieve an increased milking frequency, i.e. an increase in the number of milkings per cow per day (Oudshoorn, 2009). Compared to solutions with grazing only, combined strategies with good forage supply could give an opportunity to build a system with adjustable levels of supplements and flexible time-schemes (Davis *et al.,* 2008). Jago *et al.* (2007) showed that the average number of visits to the milk unit per cow per day could vary from 1.4 to 2.3. Taking into the account that the amount of metabolizable energy (ME) obtained from pasture is one of the limiting factors for the animal's production, Oudshoorn (2009) showed that in a long-term perspective part-time grazing systems could give desirable volumes of the energy corrected milk (ECM). By increasing number of animals per milking unit, profitable levels of the production could be achieved. This solution with part-time grazing will give the same economical outcome with maintained animal welfare and health (Kristensen *et al., 2006*).

Hernandez-Mendo *et al.* (2007) compared leg health of cows which were on pasture during a four week period with cows that were inside in a loose-house barn with concrete\rubber mats floors. Results showed general improvement in the leg health for animals with access to pasture (weekly improvements of 0.22 units per week in gait score on a scale from 1 to 5 with the step equal to 0.5).

Regula *et al.* (2004) did a survey on Swiss dairy farms using conventional systems with all-year around indoor housing or loose-house systems with summer access to pasture. According to the statistics, animals from pasture-based systems showed a significantly lower number of clinical problems with joints, teats, hoofs and skin.

Washburn *et al.* (2002) showed 1,8 times decrease in number of clinical mastitis and generally lower somatic cell levels (SCC) in the bulk milk while comparing pasture-based production systems with conventional ones.

Literature review

Grazing and automatic milking systems

In Sweden the length of the grazing season for dairy and beef cattle is regulated by law. According to "SJVFS 2012:13, Saknr L 100:3", all the cattle except bulls and calves below the age of six month and older, should have access to pasture within the certain period of time which varies from region to region and for the Uppsala area its length is minimum three months (1st of April to 31st of October). According to this regulation a period of minimum two month from the total grazing season should be within the interval from 15th of May to 15th of September.

A big number of farmers worldwide are using automatic milking systems (AMS) and have a strong opinion about profitability of such decisions when combined with grazing (Mayne *et al.,* 2011). Pastures generally represent an important resource for dairy production and quite a big part of these areas are nowadays left un-utilized due to a fact of previous extensive grazing or difficulties in planning of grazing schemes and renovation procedures (Undersander *et al.*, 2002). Numerous studies showed that with the increase both in herd size and overall production per cow per year, general number of farms using grazing in combination with AMS decreased almost 20% during last ten years (Kristinsen *et al.*, 2007; Mayne *et al.,* 2011).

Different views on grazing in the AMS

Fike *et al.* (2003) stated that high-yielding dairy cows provided only with pasture will be underfed and will also show impaired production. Fontaneli *et al*. (2005) reported that the reduction in expectable milk yield could reach 19-21% from the total yield when comparing cows kept on pasture-based diet with supplementary concentrates, with those in conventional loose-house barns fed on total mixed rations (TMR). However milk fat and milk protein contents were the same for animals in pasture-kept\loose-house barn groups and only one significant difference was in the levels of somatic cell counts (SCC) – 223.000 and 654.000 respectively.

Difficulties in the organization of feeding regimes turned pasture into a non-popular source of forage, so the most farmers are not relying on it too heavily as for the feed for high-producing dairy cattle (Undersander *et al.*, 2002).

In spite of a common opinion that grazing is not profitable while combined with AMS systems, quite many research groups have shown that the rotational and restricted grazing could provide a sustainable production system for dairy production of different scales.

Some examples could be obtained from the following studies. Dillon *et al.* (2002) showed that even a couple of hours per day for cattle on pasture could improve milk production and protein content of milk. Supporting these results, Perez-Ramirez *et al.* (2008) presented that restricted grazing with the daily allowance time of four hours could maintain grazing efficiency and positively affect milk yield and health.

Ketelaar-de Lauwere *et al.* (1999) demonstrated that cows, milked in an automatic milking unit which is continuously available during the day, will have a desirable number of milkings per cow per day even with full-time access to pasture. Furthermore, previous research performed by Krohn and Munksgaard (1993) showed that cows tend to spent more time lying down when on pasture compared to the indoor area. These findings combined with observations from a more recent study by Charlton *et al.* (2011) shows that conclusion about improved welfare for cows on pasture could be made. Charlton found that cows spent more time lying down with their head leaning on the shoulder or on the ground while resting on pasture, which was stated as an indicator of comfortable sleep (De Wilt, 1985).

Rotational and part-time grazing

Instead of continuous grazing which will lead to tired soils and slow regrowth rates for herbage, rotational grazing could keep the desirable levels of the sward dry matter quality together with the necessarily needed amounts of it (Hodgson, 1990). The term “rotational grazing” means that only one part of the pasture is grazed at the moment of time. Using the system of so called “paddocks” or small fenced parts of the pasture the farmer could keep the renovation of the sward without big economical investments or production losses (Smith *et al.*, 1986).

Flexibility of the rotational grazing system allows farmers to keep a balance between plant yield and its quality. Amount of total digestible nutrients (TDN) is high when the plant is in the vegetation phase and declines when it becomes stemmier. Cows which are switching paddocks will have the desirable length of the sward and obtain nutrients to fulfill the requirements through the grazing season (Murphy, 1999; Kristinsen *et al.*, 2005).

From the point of view of a “smart” farming a management system when the pasture forage species just receive a chance to regrow without pressure from the intensive grazing could be profitable in a long-term perspective. This system could be called “passive renovation”.

Among the advantages which could come along with part-time grazing management are:

- environmental benefits through the decreased erosion and general improvements in quality of the soil layers (Undersander *et al.*, 2002);

- advantage for the wildlife and biodiversity while keeping the landscape open and used (Parente *et al.*, 1996);

- general increase in the pasture production levels through the steady manure distribution and selective grazing which will maintain the amount of the desirable plant species (Smith *et al.*, 1987);

- aesthetical or "peaceful farming" when animals seemed more like in nature for public (De Boer *et al.*, 1994; Charlton *et al.*, 2011);

- animal welfare and health (especially when it comes to locomotory problems and mastitis incidences) (Hopster, 1996);

Dry matter quality and nutrient requirements

In parallel with the genetic development of dairy cattle the traits responsible for production, feed conversion rates and nutritional daily needs are also increasing. Peyraud *et al.* (2004) showed that pasture could provide an animal with approximately 60% of nutrients which they require in a day.

The Holstein Friesian dairy breed is one of the most common breeds on farms in Europe. In Scandinavia the population of the Scandinavian Red cattle is second in number while in Europe this place belongs to Simmental breed. Both Holstein Friesian and Scandinavian Red breeds have a high genetical potential for milk production and feed conversion efficiency ratios. However increased genetic merit index for the production traits lead to serious consequences when it comes to needs for metabolizable energy (ME) during lactation. The Holstein Friesian breed is known to easily mobilize body reserves during the early stage of lactation. It could diminish positive effects of recovery during the pasture season, mainly because high demands for dry matter intake (DMI) and ME levels in feed (Holden *et al.*, 1994; Mayne, 1995; Kolver and Muller, 1996) may be difficult to cover in a pasture based diet (Bargo *et al.*, 2003). Therefore for cows in early lactation with a high genetic potential for milk yield, pasture based diets may not be so beneficial, even though pasture is generally known to have favorable effects on cow health (Thomsen *et al*., 2006). Kolver (2003) modeled nutritional requirements for cows of 550 and 650 kg body weight and showed that high-quality pasture gives sufficient levels of ME necessary for an average yield of 35-40 kg per cow per day. In the conditions of a real farm, the actual production levels will be 80 to 90% from the modeled yield due to limitations of ME intake (Bargo *et al.*, 2003).

When it comes to high production levels and actual milk yield, the quality of the consumed dry matter, the herbage allowance and the sward structure becomes crucial. Table 1 presents comparison of daily nutrient requirements for high-producing dairy cow of a large breed (adapted from NRC, 2001) with the results of a study done by Kolver and Muller (1998). This study showed nutrient intake of cows fed on pasture-only or in a conventional barn with TMR feeding system.

Examined data about nutrient content on pasture through different grazing seasons showed that feed obtained from pasture maintained with supportive procedures aiming for re-growth could have high nutrient values (Mayne *et al.*, 2011).

For example, from experimental data presented by Roche (2011), could be concluded that fresh grass from pasture can have high nutritional values, with relatively high crude protein concentrations (22.3±2.35% DM), digestible fiber content (42.5±2.44%DM), nonstructural carbohydrate content (11.3±2.06% DM) and a moderate to high ME content (11.7±1.60 MJ ME kg^{-1} DM).

Table 1. Nutritional needs for cows and nutrients on pasture or in the conventional barn with TMR. Adapted from NRC (2001), Kolver and Muller (1998):

Nutrient requirements for dairy cattle (NRC, 2001)		***Kolver and Muller (1998)***		
Nutrient Intake:	**Cow in Mid. Lactation (BW=675kg, Yield=35 kg/day)**	**Nutrient Intake:**	**Pasture**	**TMR**
DM, kg/day	24	**DM, kg/day**	19.0	23.4
CP, % from kg DM	15.2	**CP, % from kg DM**	25.8	20.1
NDF, % from kg DM	30	**NDF, % from kg DM**	44.7	32.5
NE_l, MJ/kg	6.2	**NE_l, MJ/kg**	7.14	7.2

The greatest challenge for farmers using restricted grazing in their systems is to find appropriate levels of supplementary feed and take into consideration substitution rate which will affect herbage intake on pasture and the general motivation of cows to be outside. Table 2 shows some suggestions about supplementary feed levels for cows with different levels of milk yield.

Table 2.Suggested concentrate feed levels for high-yielding dairy cows in early and late season offered a moderate herbage allowance. Adapted from Mayne, Wright and Fisher. (1999). Grassland management under grazing and animal response:

	Early season targeted milk yield (kg/cow/day)			**Late season target milk yield (kg/cow/day)**	
	25.0	**35.0**	**40.0**	**25.0**	**35.0**
Potential milk yield from grass (kg/day)	27.0	29.4	30.9	20.0	24.5
Supplement feed level required (kg/cow/day)	0	4.5	7.0	4.0	8.5

Dry matter intake and time on pasture

Fraser and Mathews (1997) showed the complexity of cows' preferences for going out on pasture or staying indoors. According to their study, among the factors influencing cows' will to choose surrounding were: humidity, temperature inside and outside of the barn, air circulation system used in the barn, feeding regimes, distance to pasture, etc. Variety of factors affecting animals' behaviour shows that cows could choose one environment for resting, a second for socializing and third for eating depending on the situation. Results from the study done by Legrand *et al.* (2009) showed that after the morning milking, the cows preferred to stay indoors when highly palatable feed was available. During the day time when the weather was good the cows spent almost 93% of their time on pasture – grazing and ruminating. The study also showed that the results could be influenced by previous rearing experience of the dairy cattle. Diurnal rhythms and weather fluctuations during the grazing season could also inflict total time spent on pasture.

Charlton *et al.* (2011) compared preferences of cows which were fed indoors with cows receiving the same type of feed on pasture. The results showed that in 72% of all cases the animals chose pasture. Supporting these results, other researchers have also shown that cattle had a tendency to spend up to 65% of their time on pasture during summer months if provided with such an opportunity (Ketelaar de Lauwere *et al.,* 1999; Spörndly and Wredle, 2004). However, the time spent on pasture has been shown to be highly dependent on the walking distance and organization of cow-traffic (Spörndly and Wredle, 2004).

One of the crucial aspects which usually create a point for discussion is fetching cows from the field. Jago *et al.* (2011) showed that well organized cow-traffic could definitely maintain the number of visits to the milking unit without affecting the costs for labor. The main part here lies in the understanding of cow behaviour and preference between indoor and outdoor space. Cows usually show signs of fear towards novel objects and changes in the herding routines. Familiarization and training could be a way to solve this problem. Results from the same study showed that both young and old cows performed better in a barn with guided cow-traffic system if introduced to it by calm gentle herdsman and if received concentrates during the milking. The same study also showed that cows will return from pasture on their own expecting feed being delivered to feeding troughs. Habituation to barn\pasture layout and feeding regimes adjusted to keep the motivation of animals to return to the indoor-environment to be fed and get access to resting area could be a key-factor to necessary amount of visits to the milking unit. Gregorini *et al.* (2009) showed that cows from part-time grazing systems consumed approximately 70% of their daily herbage mass within the first four hours after getting access to a new paddock. Both studies show the importance of planning the rotational grazing systems in a way to achieve maximal profitability with limited resources.

Greenwood and Demment (1988) showed that the duration of grazing periods is not a determining factor for DMI. Animals adjusted their grazing behaviour and efficiency on pasture by decreasing the time spent rumination and resting outdoors. Kennedy *et al.* (2008) and Perez-Ramirez *et al.* (2009) studied cows with 3, 4.5, 9 and 22 hours of access to pasture daily and the results showed that the daily herbage intake was minimally dependent on time allowances for cattle to be on pasture and that the cattle had peaks of grazing activity which had approximately the same duration for all treatments. The different time intervals did not show any influence on the amount of consumed grass and obtained dry matter intake (DMI) within the range of times studied.

Materials and methods

Aim

The aim of the experiment was to investigate how different pasture allowances (exercise pasture only vs. production pasture) and different levels of supplementary feed, affected the behaviour and production of dairy cattle (*Bos Taurus*) milked in an AM barn and with restricted time-access to the pasture area.

Questions

- How will the intake of indoor supplements differ between the cows on production pasture and the cows on exercise pasture?
- How will the milk yield be affected by access to production or exercise pastures?
- How will the feed costs be affected by the production or exercise pasture?
- How will access to production or exercise pasture affect grazing, and resting behaviours and the cows´ motivation for being on pasture?

Hypothesis

Compared with cows on exercise pasture grazing the same small field daily, cows on production pasture with new pasture daily at a high pasture allowance will have:

- Longer grazing times compared with cows on exercise pasture
- Lower intake of supplementary feed indoors compared with cow on exercise pasture
- A higher milk yield compared with cows on exercise pasture;
- A lower feed cost compared with cows on exercise pasture;
- Increased motivation to go out to graze

Exercise pasture can lead to:

- Increased frequency of lying and resting behaviours

This study was performed with total duration from 1st of May 2012 till 31st of July 2012 including preparation and adaptation periods. According to the plan, experimental start was planned to take place on 8th of May with the start of the pasture season beginning with one week adaptation to the pasture conditions followed by 11 experimental weeks and ending on July 31st. Due to a delay in the construction of a cow lane and technical difficulties with the installation and adjustment selection gates, the date of the actual let-out onto pasture was moved to 28th of May and the experimental start to June 8th. Actual time for cows being on pasture was 9 weeks including 2 weeks period for adaptation and establishment of the technical equipment giving a total of 7 experimental weeks. The experiment was held at the newly built national research livestock facility at Lövsta.

Treatments:

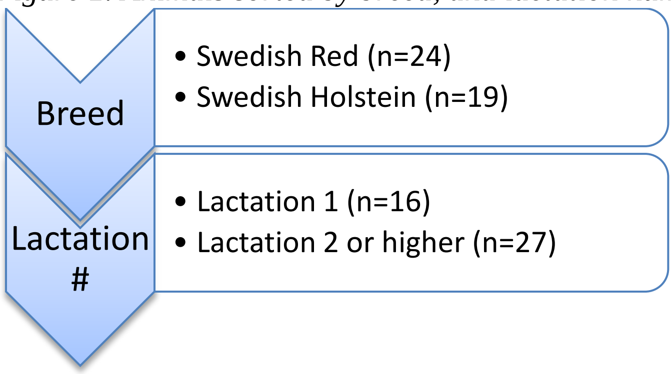
Exercise pasture (E):
This group consisted of 22 animals who had access to a pasture area of 1 ha and a stocking rate of 22 cows/ha. The animals had access to the exercise pasture during ten hours daily (06-16h). The group with exercise pasture had access to silage *ad libitum* throughout the day (24 h).

Production pasture (P):
Number of animals in this group was the same, as for the first treatment – 22. Group 2 was grazing in the twelve small paddocks in a rotation system with access to a pasture area of 0.6 ha daily giving a total pasture area of 7.2 ha and a planned stocking rate of 3 cows/ha. The animals had access to the production pasture during ten hours daily (06.00-16.00) Cows remaining outdoors were brought back to the barn at 16 hours. Silage was available ad libitum in the barn in the afternoon and night (14-06 hours) but not during the main grazing hours (06-14).

For both treatment groups concentrate allowance was given according to calculated requirements and an assumed intake of roughage (silage+pasture) of 12 kg DM. Requirements were based on milk yield and live weight at experimental start and adjusted every week during the experiment. The weekly adjustment was based on an estimated milk yield decrease of 0.4 kg energy corrected milk (ECM) per week (for details see diets in Appendix 1). The concentrate used was a commercial mixture called Solid 620 from “Lantmännen Lantbruk” (CP=182 g/kg DM, NDF=302 g/kg DM, ME=13.2 MJ/kg DM).

Animals:
Forty four cows past lactation week 10 took part in the experiment. The animals were of the Swedish Holstein and Swedish Red breed. Average days in milk (DIM) parameter for cows in the experiment were 141.2 with range from 67 to 222. Animals within the same breed and parity group (first calvers and older cows) were randomized to the two treatments. One cow was excluded from the data analysis due to mastitis during the experiment and therefore a total of 43 cows were included in the final analysis. More detailed information could be obtained from Figure 1.

Figure 1. Animals sorted by breed, and lactation number:



Housing and management:

Cows were kept in a free stall barn equipped with VMS™ unit (DeLaval Voluntary Milking System) h with access to pasture from 06.00 till 16.00 h daily. Passages to the to the exercise- and pasture areas were separate and a selection gate (DeLaval Smart Selection Gates) near the barn exit directed each cow to the right pasture based on her treatment group. Gates in the barn prevented all cows from entering the indoor resting area inside with concentrate feeders between 06.00 and 14.00 hours with the objective to increase cow motivation to pasture during the hours of pasture access. Before doors to the pasture were opened in the morning, milking status of every cow from the experimental groups was checked and cows which had not been milked for 10 or more hours were directed to the milking unit The experimental routines included no fetching of cows from the field during the grazing hours but only fetching of cows remaining in the fields at 16.00 when the barn doors were closed.

Fields:

The planned pasture area was 6 ha and 1 ha for the production and exercise pasture groups respectively. An additional 3 ha pasture area was available as a reserve area in case of pasture shortage. Paddocks for everyday grazing were 6000 m^2 (60x100 m) and the paddock used for the exercise group was 1 ha. For the production group rotation took place on a total area of 6 ha. Details about pasture layout could be obtained from Appendix 2.

Pasture management:

To ensure a sufficient amount and quality of grass throughout the season management procedures were as followed:

- Cutting of residual herbage after grazing was performed 3 times per week to promote high quality regrowth. Fertilizer was applied directly after cutting on two occasions during the experiment. The amount corresponded to a total amount of 200 kg N over the entire grazing season (120 days) and the amount was adjusted to the number of pasture days completed at the time of application. The earlier mentioned delay of the pasture let-out and experimental start made it necessary to cut approximately 2 ha of pasture in early season to maintain the pasture at a leafy stage and avoid the development of corse, stemmy pasture of low digestibility.

Measurements and sampling in the field:

Sampling squares:

Herbage allowance on the production pasture was measured every weekday by cutting ten squares that were randomly distributed over the paddock which was to be grazed the next day. The grass within the measuring frame (50x20 cm) was cut at 3 cm height from the ground. In

the exercise pasture the same procedure (cutting) and measurement of sward height and sampling for nutrient content was performed two times per week.
The material from each square was dried in the drying cupboard at 60 degrees Celsius during 18 hours. The weight of the dried grass was noted and put into the protocol. Calculation of dry matter per ha and herbage allowance could thereafter be performed.

Sward Height and hand plucked samples:
Sward height was measured every weekday for the production pasture and twice a week for the exercise pasture. Sward height was measured with a falling plate meter (30*30 cm; 430-433 g) with 20 measurements per paddock which was grazed that day for the production pasture (60x100 m) and 20 measurements for the exercise pasture (1 ha) were done per day of sampling. In connection with height measurements, hand plucked samples was collected for laboratory analysis of nutrient content, trying to observe and imitate cow grazing in the field. In a similar manner as for the cut samples, the hand plucked samples from the previous week were pooled over one week periods for laboratory analysis.
The laboratory analyses performed on the hand plucked samples were: Dry matter (DM), Crude protein, Neutral detergent fiber (NDF) and rumen fluid soluble organic matter (VOS). Kjeldahl method was used for evaluation of crude protein content (Nordic Committee on Food Analysis, 1976); NDF was analyzed by using Chai and Uden method (1998). Metabolizable energy was estimated according to Lindgren (1979) and was taking into the account levels of VOS in dried samples.

Test milking and milk sampling:

Milk samples were taken before experimental start and then every second week through the whole experimental period. The samples were analyzed for: fat, protein and lactose. Somatic cell count was determined once a month.

All the milk samples were collected in the VMS unit using the standard sampling device and milk sampling function of the DelPro software. Two samples were collected for every animal within a 24 hour interval.

Live Weight:

Animals were weighed three times during the study – in the beginning before pasture let out, in the middle and one week before the end of the experimental period.

Behaviour studies:

During the experiment behavior studies were performed three times with at least one week interval. To identify the cows, the number of every animal was painted on both sides using ordinary water soluble paint.

The following procedures were used to on the days of behavior recordings:

- Behavior observations were performed during the entire period that animals had access to the pasture/exercise area, i.e. 06.00-16.00 hours.
- Observations were performed on all 44 experimental cows
- The two groups of animals were observed by one person each, using scan sampling with instantaneous recording every 15 minutes with a total duration of ten hours. The animals were scanned in the same order within every 15 minute interval;

The following things were recorded:

- Where the animal was: pasture area, cow lane or indoors in the barn;
- The position of the cow (if she was outdoors): standing or lying down;
- Activity (if the cow was outdoors): grazing, ruminating or other;

Detailed descriptions of the behaviors can be found in Appendix 3.

Statistical analysis:

Statistical analysis for the main milk production parameters included 43 out of 44 animals from two treatment groups.
For the statistical analysis the software from Statistical Analysis Systems (SAS, 2008) was used. A variance analysis was performed with the GLM procedure (general linear model) to describe differences between different production and behavioral parameters. Data from production and behavior parameters were checked for normal distribution using the Univariate procedure in SAS.

Average for the main production parameters for all 7 weeks of the experiment was calculated. For the analysis of the different dependent production variables "Y"(i.e. milk yield, milking interval, milking frequency, kg ECM, SCC, as well as protein, fat and lactose content in milk), values for these parameters immediately before the start of the experiment were used as co-variates in the statistical analysis.

The following independent variables and their interactions were tested:

Treatment (class variable): production pasture group or exercise pasture group;
Parity (class variable) first calver or older cow;
Days in milk/DIM (continuous variable);
Breed (class variable): Swedish Red or Swedish Holstein;

The variables DIM and breed were not significant and therefore excluded from the final analysis.

The final model for the production parameters thus contained the effect of the independent variables in the following model:
Y= Treatment Parity Treatment*Parity
The results are presented as least square means with the standard error in parenthesis for the effect of different variables on the response variables.

The behavior study was performed three times during the experiment with 10-hour observation periods per session and with 15-minute intervals giving total of 120 observations per cow (3 days*10 hours*4 times/hour). All the behaviours were calculated as averages in % from the total observation time. Thus the response variables (i.e. different behaviours, as % of the total observation time) were analyzed in a model where the effects of the following independent variables and their interactions were tested in the statistical analysis:

Treatment (class variable): production pasture group or exercise pasture group;
Parity (class variable) first calver or older cow;
DIM (continuous variable) days in milk;
Breed (class variable): Swedish Red or Swedish Holstein;

The variables parity, DIM and the interactions between them were excluded from the final model due to non-significant influence on the results. Furthermore, the interactions between the effect of treatment, effect of breed and effect of parity were not significant and therefore also excluded from the final model for the behavior variables.

The final model for the analysis of the behavior variables thus included the following parameters:
Behaviour = effect of treatment + effect of parity + effect of breed.

Data and reliability:

During the experiment a number of technical problems led to the fact that the indoor feeding was not implemented in a reliable way which affected the treatments (see below). Due to this, a big part of the feed intake data was lost and cannot be included in the final analysis.

The data which is correct with regard to data collection and measurements is the following:

- data from the behavioural
- milk production data;
- pasture production data;

Feed trough problem:

The feeding equipment for roughage at the Lövsta research barn consists of automatic feed troughs from the Norwegian company "BioControl". The feed troughs rest on weight cells and the content in each feed trough is therefore known and registered in software connected to the feed troughs when they are filled up several times daily (7-9). The access to the feed troughs is monitored by transponders that the cows carry around their necks and cows in different experimental groups can be put in groups with access to different amounts of roughage or - in some cases they can be programmed to have access to the feed troughs only during certain times of the 24 hour period.
When a cow with permission to eat roughage enters a feed trough and starts eating, the software connected to the trough registers the entrance of the cow and thereafter how much the weight of the feed in the trough decreases as the cow eats. The time that the cow is eating is also registered. Therefore it is possible to measure the individual feed intake of each cow, the number of meals and the amount eaten at each meal, the eating speed and a number of parameters that describe the feeding pattern of the individual cow or a group of cows. The BioControl feed troughs were previously used at the earlier research station at Kungsängen Research Center. The previous experience from the experiments held at Kungsängen research center showed that the data obtained from this system was fairly reliable and the general level of the technical issues was minimal in terms of the interference with the study results.

During the experimental period in the present experiment at Lövsta, however, the following situation occurred:

- Feed troughs started to register zero-intake for some cows during the day, but without visual or documented changes in the production or behavior. This led to increased control over the actual intake in the system log-files.

- Animals from the production pasture group which were not supposed to have access to the roughage feed troughs during the daytime period 06-14 hours were noticed to be eating in the feed troughs at times between 06-14 hours i.e. when they were not supposed to have access to indoor roughage. Their intake was registered on other cow numbers indicating that they had scared away another cow to access the roughage they were consuming. This led to software checks in the VMS office on both the feedcontroling-processor for the feed troughs (feed trough software) and on the VMS-computer responsible for the scheduled feeding time. Upcoming days showed that the problem remained unsolved. Reading the “BioControl” manuals and further changes in settings did not change the general situation.

- It was decided to make mechanical adjustments of the individual feeding space in every trough. The objective of this adjustment was to prevent high ranked cows without daytime access to supplementary roughage, to scare away cows in the exercise group who according to the experimental plan had 24 hour access to silage indoors. The objective was to eliminate silage stealing between the experimental animals.

- One reason for the problems that occurred was that there had been a power breakdown in the barn. Power breakdowns set the system and feedcontroling-processor to the default settings making the control for the previously made changes impossible. The staff and researchers were unaware of the fact that the default settings were unsuitable for the research barn and the people with knowledge of what the default settings should be were on holiday. Therefore the problem remained unsolved.

- The experienced staff from the Kungsängen research center was consulted when the problem continued and manual changes in the time-out settings of the feed troughs were made aiming at shortening the time-intervals needed for the trough to close.

- The problem still remained but it was not possible to establish contact with technical and software support from “BioControl” due to the summer holidays/shortage of technicians/internal “BioControl” failures.

- Finally a contact was established and a visit from the “BioControl” (main developer and engineer) and resetting of a number of values in the system (time for opening and closing of gates etc.) seemed to solve most of the issues. However, there still remained a problem unsolved. The problem was that sometimes the system did not seem to register the switch to a new day at midnight, The BioControl staff promised to solve the problem and return soon to put it right.

Results

General

The problems with the feed troughs described above meant that the treatment that the animals in the production pasture group actually were subjected to, was only partly what had been planned. A short summary of the actual treatments in the experiment follows here:

Exercise pasture (E): Treatment for cows in this group was approximately as planned, i.e. access to an exercise field during ten hours per day (06-16 h) and indoor silage feeding *ad libitum* 24 hours/day.

Production pasture (P): Cows in this group were offered new high quality pasture daily at a high daily allowance with access to the grazing area ten hours per day (06-16 hours). Cows in this group were planned to have access to ad libitum indoor silage only between 14.00-06 hours. The plan was that the animals would have no access to silage between 06-14 h, but in reality many cows could steal silage from other cows and it is probable that more dominant cows had more or less free access to silage throughout the 24 h period while low ranked cows were not able to access silage daytime.

Behaviour studies

Cows from the exercise and production groups spent approximately the same time on pasture, which was (3h 28min) and (3h 22min) respectively with no difference between breeds. Table 4 presents some of the important behaviours in percentage of total observation time (10h). Regarding the actual grazing activity there was no significant difference between the two treatments. The Swedish Red breed, however, spent significantly 5% more time grazing compared with the Swedish Holstein, corresponding to almost 30 minutes of actual grazing. The Swedish Red also spent significantly more time standing outdoors compared with the Swedish Holstein: +5.6% more of the outdoor period, corresponding to 34 minutes. There was no significant difference in time spent outdoors on pasture or in the cow lane between breeds or treatments. The group with production pasture spent significantly more time standing up compared to cows on exercise pasture.

*Table 4. Results from behaviour observations. Percent of observation time (10 hours) that the animals on different treatments and of different breeds performed different behaviours. Number of animals used for the analysis (N)=43. Values for the behaviours expressed in Least Square Means and significance values for the effects are expressed as p-values. (NS: non-significant; Tendency: p≤0.1; *: p≤0.05; **: p≤0.01):*

Behavior studied	Exercise	Production	Effect of treatment	Sw. Red	Holstein	Effect of breed
Grazing activity	**21.2**	**23,9**	**0.14**	**24,8**	**20,1**	**(*) 0.014**
Standing Out	**27,5**	**31,3**	**(*) 0.05**	**32,0**	**26,8**	**(**) 0.01**
Cow lane	**6,3**	**6,9**	**(NS) 0.3**	**7,0**	**6,2**	**(NS) 0.2**
Laying out	**13.2**	**8,7**	**(*) 0.013**	**9,5**	**12.4**	**(NS) 0.1**
Time on pasture	**34.6**	**33,6**	**(NS) 0.6**	**34,8**	**33,4**	**(NS) 0.4**
Time indoors	**59,1**	**59,5**	**(NS) 0.8**	**58,2**	**60.1**	**(NS) 0.3**

Figures 2, 3 and 4 present % from total number of cows both from exercise and production groups who was on pasture during different hours of the three days of observations. Temperature fluctuations during these days can be seen in figure 5. All three days of behaviour studies were sunny, with no rain, partly-cloudy periods and a wind of 2-4 m/s. According to figures 2, 3 and 4, peaks of activity and general motivation for most of the cows to be outdoors were between six in the morning, when the doors from the barn were opened, until noon.

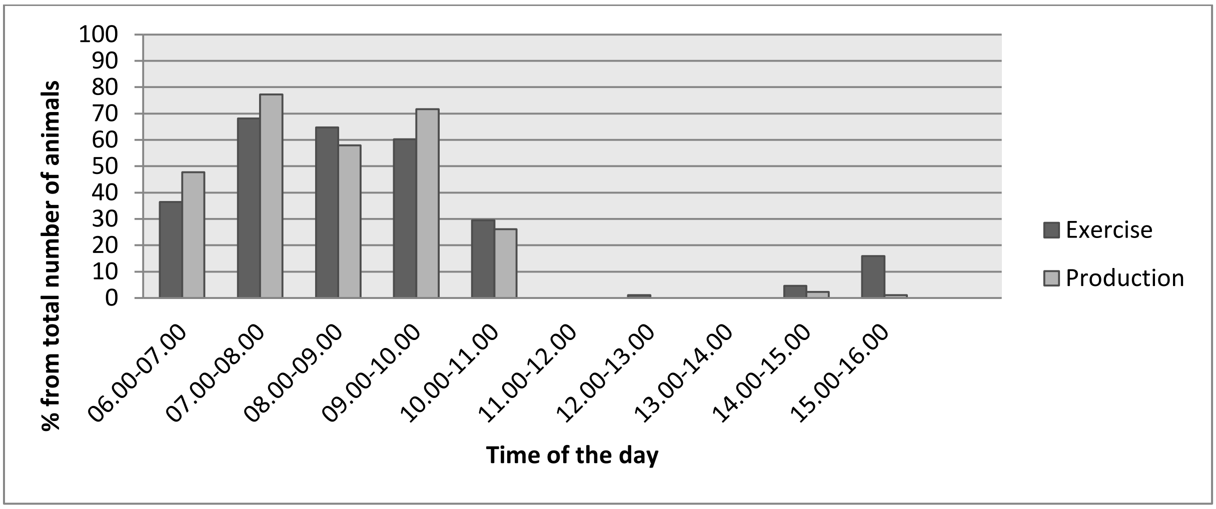


Figure 2. Outdoor activity for production and exercise groups 26/6-2012.

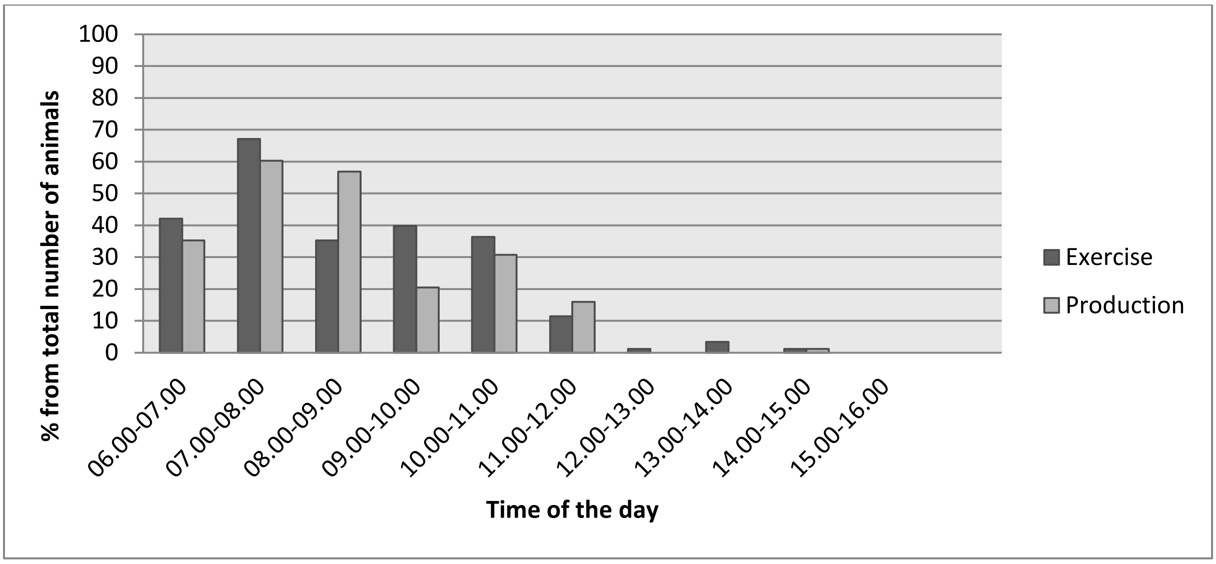


Figure 3. Outdoor activity for production and exercise groups 29/6-2012.

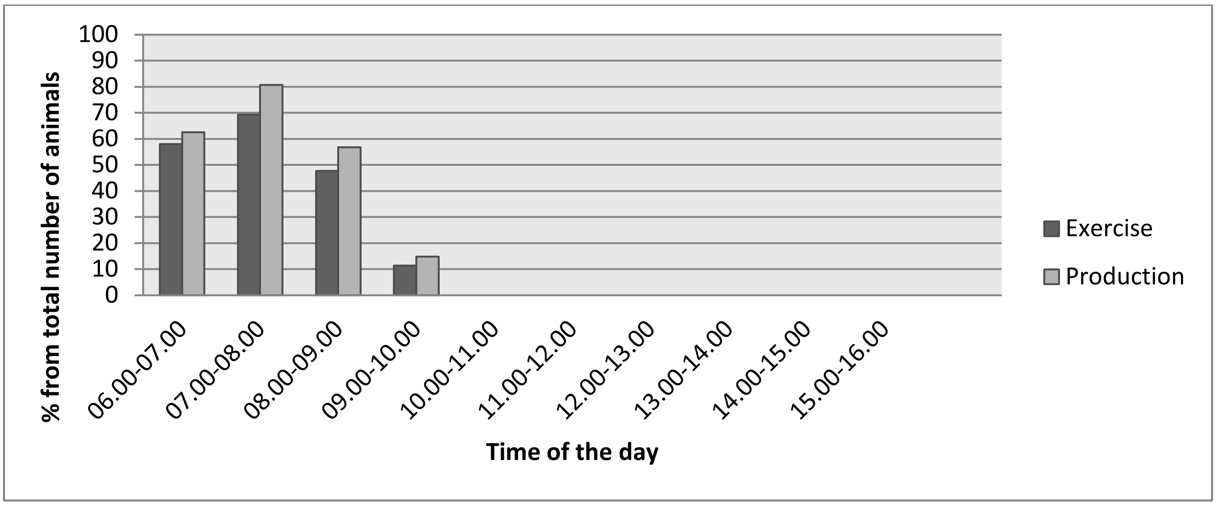
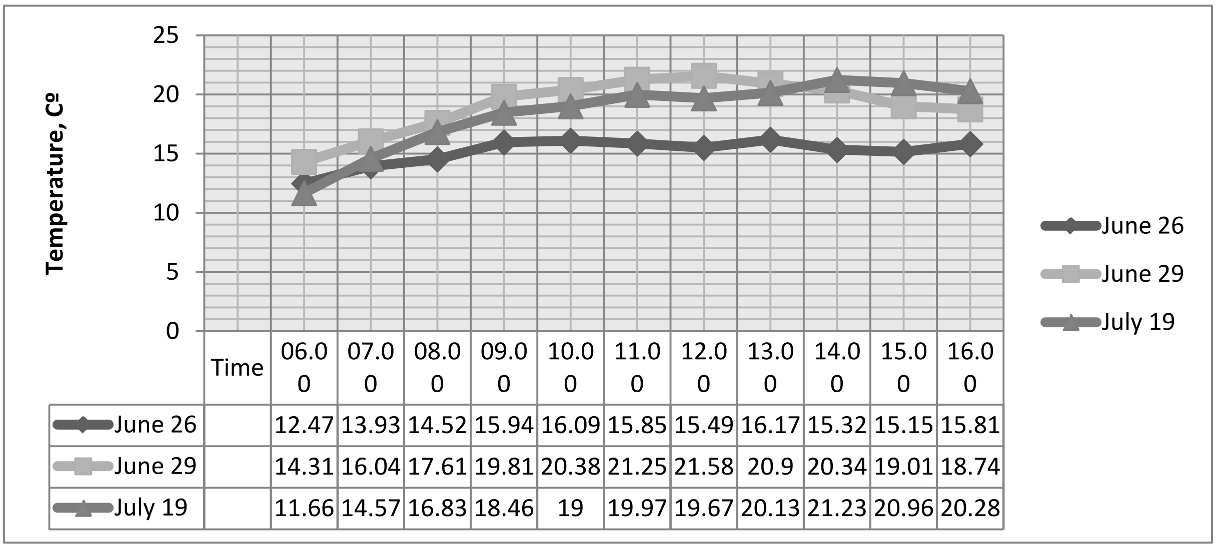


Figure 4. Outdoor activity for production and exercise groups 19/7-2012.



	Time	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
June 26		12.47	13.93	14.52	15.94	16.09	15.85	15.49	16.17	15.32	15.15	15.81
June 29		14.31	16.04	17.61	19.81	20.38	21.25	21.58	20.9	20.34	19.01	18.74
July 19		11.66	14.57	16.83	18.46	19	19.97	19.67	20.13	21.23	20.96	20.28

Figure 5. Temperature fluctuations during the days of observations.

Pasture data

Figure 6 represents tendencies in the amount of kg DMI per cow per day for both exercise and production pastures through the whole experimental period.

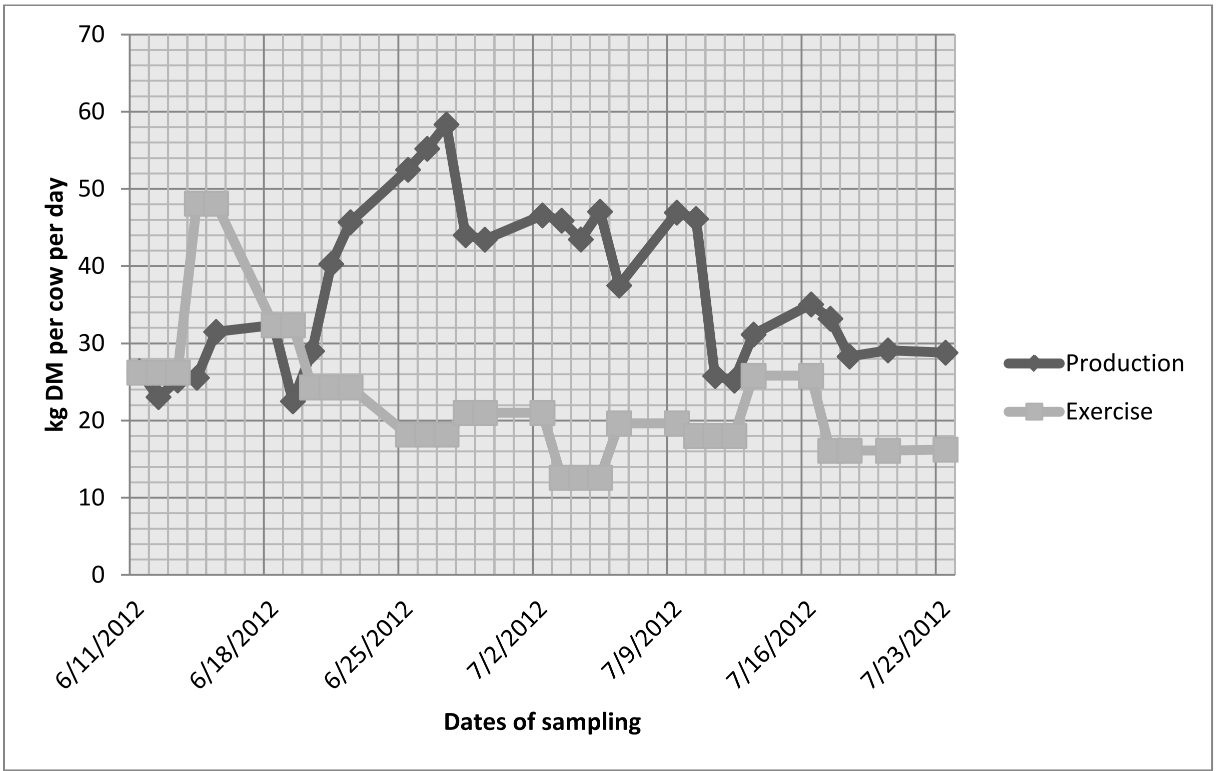


Figure 6. Available forage, amount of kg DM per cow per day.

Growth conditions for the pasture were very favorable with plenty of rain throughout the season. According to the results from the pasture cuttings, herbage allowance in the exercise pasture group decreased from very high levels in the beginning of the experiment and stabilized to a level around 20 kg DM/cow and day after approximately 10 experimental days. The herbage allowance in the production pasture group was initially somewhat lower compared with the exercise pasture, thereafter rising to a very high level and from there steadily decreasing and reaching approximately 30 kg DM/cow and day towards the end of the experiment. Proportion of grass\clover on the pasture according to samples taken towards the end of the experiment was approximately 50:50.

Data about nutritional values of the herbage from pasture could be obtained from Table 4.

Table 4. Quality of the grass samples (in % from the weight of the dried sample) obtained from exercise (Ex.) and production (Prod.) pastures:

Component	**Treatment**	**11-15/6**	**18-22/6**	**25-29/6**	**2-6/7**	**Average**
Ash, % of DM	*Exercise*	7,7	8,8	10,1	10,5	9,3
	Production	7,4	8,0	9,2	10,4	8,8
Crude protein, % of DM	*Exercise*	8,9	11,1	11,4	15,0	11,6
	Production	10,3	11,5	14,8	14,4	12,8
NDF, % of DM	*Exercise*	51,7	50,5	47,7	41,2	47,8
	Production	52,5	51,1	47,1	42,1	48,2
VOS	*Exercise*	87,8	86,3	84,7	83,9	85,7
	Production	90,3	87,4	84,4	81,4	85,9
ME, MJ/kg DM	*Exercise*	11,2	10,8	10,5	10,3	10,7
	Production	11,6	11,1	10,5	10	10,8

Sward height on production and exercise pastures and changes through the grazing season are presented in figure 7.

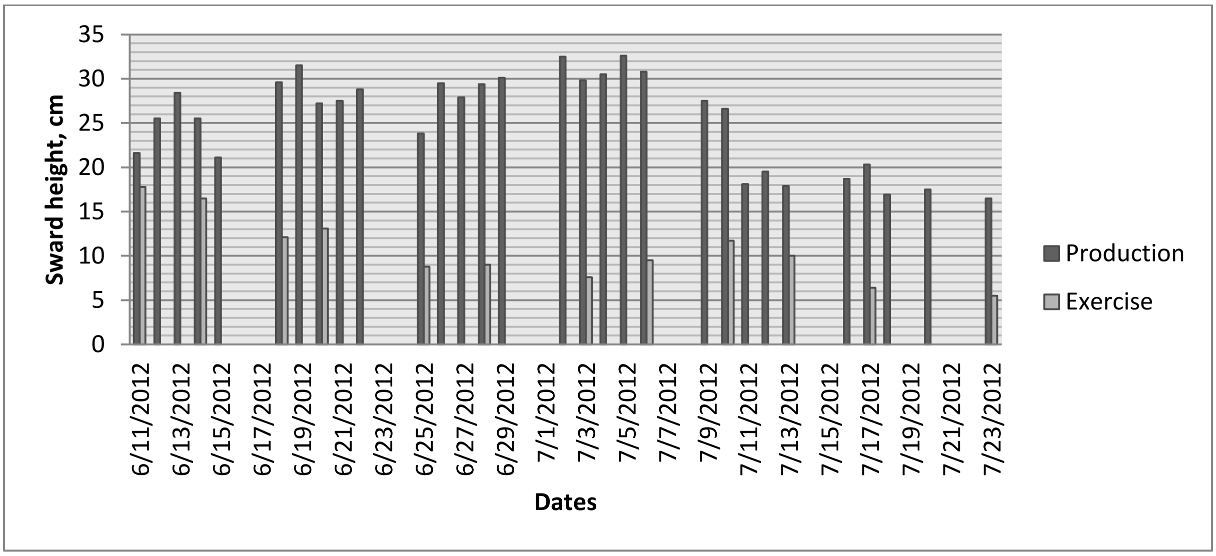


Figure 7. Changes in the sward height on production and exercise pastures.

Milk production data

Milking frequency is presented in figure 8. For milking frequency and milk yield, there was a significant interaction between treatment and parity. There was a significant difference ($p \leq 0.05$)between first parity cows from the exercise and production groups but no significant difference between older cows with parity number two and higher.

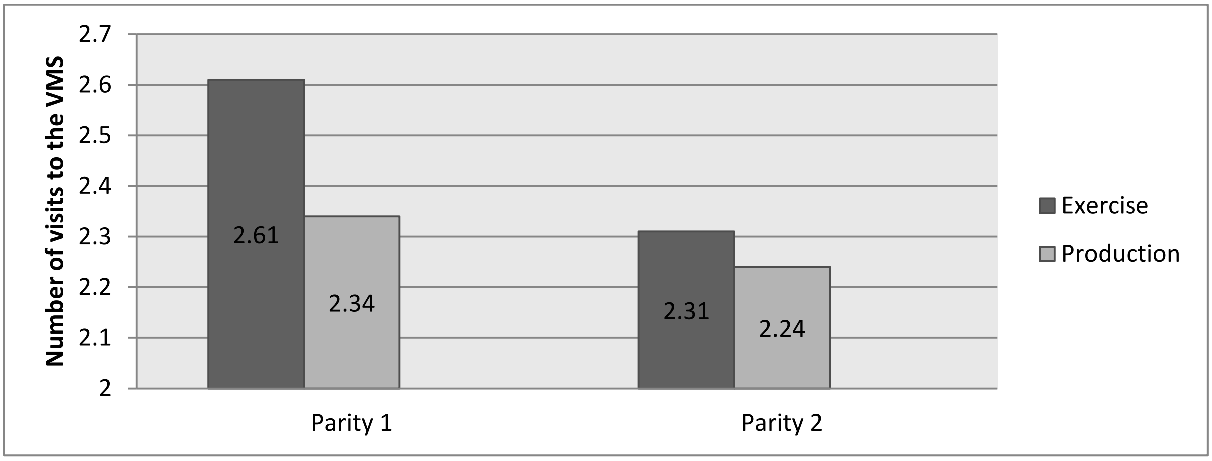


Figure 8. Milking frequency for first parity cows and older cows in the two treatment groups.

The milk yield results are based on the statistical analysis of averages for each cow obtained from all the milkings during the entire experimental period. The results are presented in Figure 9. There was a tendency for a higher milk yield ($p \leq 0,1$) for the first parity cows from exercise pasture group compared to production pasture group. There was a significant difference between treatments for older cows where cows with parity two and higher milked more in the production group ($p \leq 0,001$).

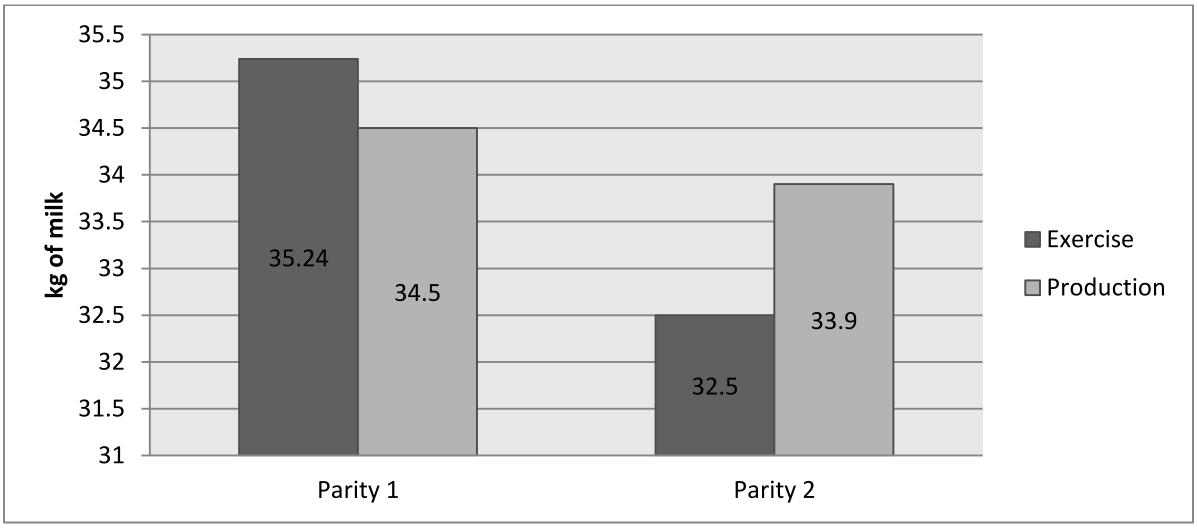


Figure 9. Average milk yield through the whole experimental period.

There was no significant difference between younger cows from exercise and production groups in terms of energy corrected milk (ECM) yield, but a tendency for older cows ($p \leq 0,1$) milking more on production pasture. Data for ECM yield is presented in figure 10.

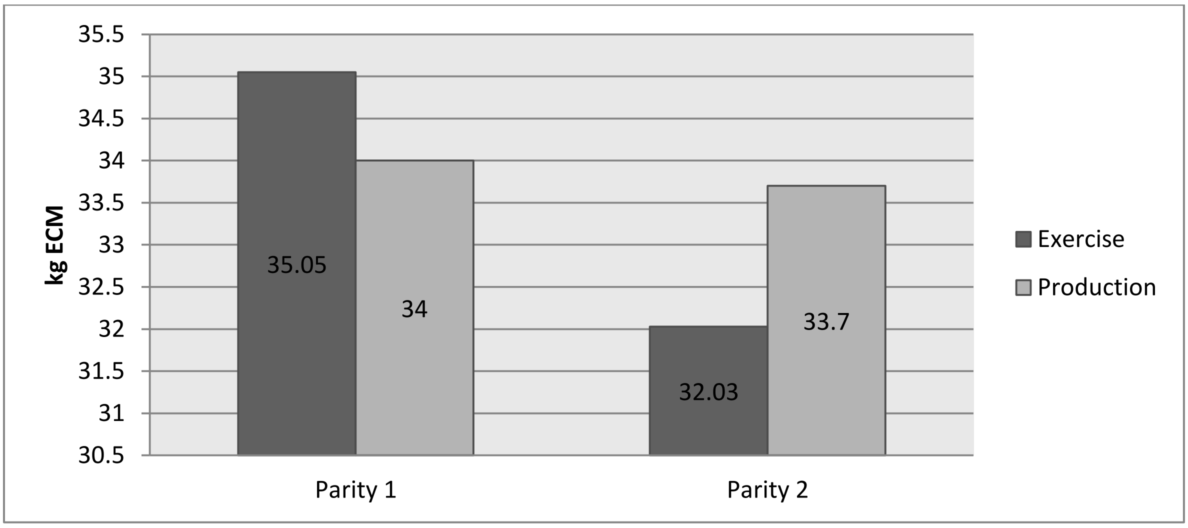


Figure 10. ECM yield for cows on production and exercise pastures.

Main production parameters are presented in figure 11. There was no significant difference in any of the categories.

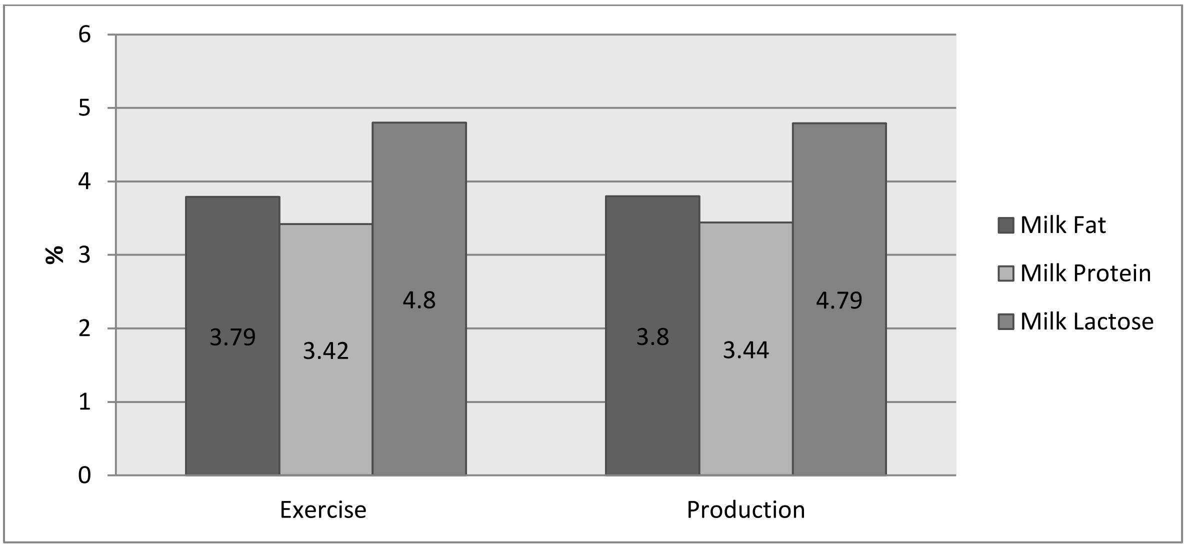


Figure 11. Milk fat, milk protein and milk lactose values.

Discussion

Part-time grazing and automatic milking system

The results of the experiment showed that the combination of restricted access to pasture and automatic milking system could be successful without serious management difficulties. There was no problem with cows visiting the AMS unit according to their own will and the general milking frequency was higher for both experimental groups compared to the commonly used conventional twice-a-day milking routine.

A combination of restricted access to pasture combined with indoor feeding could be an interesting solution and would secure the positive effects of grazing on health and welfare of animals (Thomsen *et al.*, 2006). De Wilt (1985), Krohn and Munksgaard (1993), Kilgour (2012) and many others proved that cows tend to spend more time on pasture showing the signs of more comfortable movement patterns and resting behaviour. Results from our study partly support these statements by showing how the many of the cows chose to go to the pasture immediately after the doors from the barn were opened. The cows' desire to be outside was not dependent on times when feed was distributed in the barn or any other interfering factors like herding or fetching from barn staff.

A relatively low grazing activity was observed in this experiment. This could partly be explained by problems with the feed troughs and the fact that the silage was available for most of the cows from both treatment groups through the whole 24-hours period. It is also difficult to collect data about actual intake from grazing on pasture and connect it to cows' preference of certain type of feed (Charlton *et al.*, 2011).

During the experimental period an effect of social facilitation and synchronized behaviour were clearly pronounced. Animals in our study tended to go out to the pasture in a more synchronized way – always leaving the barn in the company of at least one other cow. The same was applied to the grazing activity and returning back to the barn – animals were doing everything in small groups which were following one another within short intervals of time.

Factors influencing the cows' behaviour

The differences in grazing activity between Swedish Holstein and Swedish Red (24.8% vs 20.1%) could be explained by a number of reasons. Referring to studies done by

Kashiwamura *et al.* (2001) and Jago and Keerisk (2011), psycho-social reactivity and learning ability could differ between different breeds. Swedish Holstein is a high-producing dairy breed with big nutritional demands and genetic traits aiming for the best efficiency in feed conversion and high milk yield. High rates of production predispose higher consumption rates and could lead to prioritizing need to eat to such needs as lying and resting. This could partly explain that the first priority for this breed is to cover high nutritional demands and get desirable amount of DM per day even compared to Swedish Red. It is easily achieved indoors where feed troughs are available during the day together with concentrate feeders after the passage through the AMS unit. Some researchers (Charlton *et al.*, 2011) explain time for cows to be on pasture and graze by previous rearing experience and production system used on the original farm. Animals of the Swedish Holstein bred in the experiment came to Lövsta research center from different regions of the country and it could partly explain their will to spend more time indoors in a familiar surrounding with "easy" feed sources, even when having access to pasture. As a contrast, animals of the Swedish Red breed at Lövsta came from the previous university herd at Kungsängen and these animals were accustomed to being in pasture in the summertime. Even considering the results from study done by Jago and Keerisk (2011) which showed that the adaptation period for cows with no previous grazing experience is relatively short, factor of novelty should still be taken into the account.

The significant difference (13.2% for exercise group and 8.7% for production group) in lying behaviour between groups could be explained by a higher level of a psychological comfort for animals on exercise pasture. Animals tend to spend more time resting in a familiar, comfortable surrounding with well-learned pathways to it and established walking distances. Spörndly and Wredle (2004) showed that the walking distance could have influence on cow's willing for being on pasture. Animals from the production pasture group were offered a new pasture area daily and therefore they changed paddocks on a regular basis. Sometimes walking distances from the stable to grazing area were quite long. Additionally the animals from the exercise group were walking more or less in a straight cow lane towards their pasture, while animals from the production groups in some cases needed to turn 90 degrees to enter a smaller cow track leading to the new daily pasture area. Returning to the social facilitation effect, it was much harder for a single animal to see familiar cows from its own group when the paddock was situated to the side, out of direct straightforward vision.

Additional feed inside of the barn could seriously affect DM intake on pasture and general time for being out. Charlton *et al.* (2011) showed an influence of additional feed supply on cows' motivation to graze and on pasture daily intake.

A possible influence of weather on grazing activity could be taken aside due to the fact that usually the cows were back to stable at around 11.00 in the morning when solar activity was not that high. Temperature and wind during the days of observation could be characterized as moderate so there was no need for animals to seek shelter inside the barn to hide from uncomfortable climatic conditions.

The general decrease in time for being on pasture during the last day of observations could be explained by total length of grazing season and decrease in sward height together with nutritional quality of herbage. Ketelaar-de Lauwere and Ipema (2002) showed a direct connection between height of grass available on pasture and cows' motivation for foraging.

Sward quality and herbage allowance

Figure 6 presents the situation with the amount of DM per cow per day. The summer of 2012 was characterized by high rates of precipitation and good sward renovation which partly minimized main difference between exercise and production pastures – height of sward and regrowth rates. It was expected that the exercise area with constant grazing pressure will have lower nutritional values compare with the production pasture where certain maintaining and supportive procedures were performed. Due to the weather situation and the fact that this area was used for grazing after a long period of staying untapped – nutritional values and amount of DM should not be surprising. However figure 6 shows a declining tendency for the DM content on exercise pasture while production pasture keeps stable values through the whole experimental period. These results are highly dependent on the current weather situation and even with good management routines stay quite unpredictable in terms of expected herbage yield and nutritional quality.

Chemical analysis of the samples from both exercise and production pastures showed approximately the same levels of metabolizable energy and crude protein which led to similar result in milk production for cows from the two experimental groups. The low values of crude protein in the pasture were surprising, especially as pastures were fertilized with nitrogen on two occasions. However, the comparatively rainy weather seems to have given lower protein contents also in harvested grass during the season of 2013 (Spörndly, 2013).

Milk production

The significant difference in milking frequency (2.61 and 2.34 for exercise and production groups, respectively) for young cows compared with older cows (2.31 and 2.24 for exercise and production groups, respectively) could be partly supported by the results from Kawashimura *et al.* (2001), which showed an ability of primiparous cows to learn faster in novel situations. This means that the adaptation to changes in cow traffic system used in our experiment was faster for first calvers compared to older animals and that young cows were able to find their way from pasture to milking unit faster. Data from figure 9 about milk yield could be explained by problems with feed troughs that occurred during the experiment and therefore diminished difference between treatments in forms of obtained DM and its sources.

The same line of reasoning can also be applied to the main production parameters such as contents of fat, protein and lactose in milk. Inability to control silage intake and high quality pasture on both treatments led to similar nutritional condition for both exercise and production groups.

Evaluation of the experimental set-up and technical issues

The main part of the technical problems and silage intake data which was lost, were related to difficulties with settings for the automatic feeding troughs. The controlling processor (Photo 1) in combination with software for scheduling time of access to feed for different groups had been used in many experiments with good results earlier. However, when the feed troughs were moved to the new experimental barn they were screwed up with a larger distance between the sides compared to the earlier set-up giving a larger feed space and the opportunity for dominant cows to force their way into feed troughs that they were not supposed to be able to access. Furthermore, the move to a new barn led to a change in routines and responsibilities so that knowledge about the software for the feed troughs was lost or not accessible during the time of the experiment. Our main problem was related to the inability of the program part of the feeding troughs to control the access for cows from different groups – exercise with full ad libitum access and production with restricted feed consumption. From the technical point of view, sensors responsible for registering presence of animal in feed trough could have had shorter time of response and make control checks for animal-id within shorter intervals. Mechanical adjustments of feeding space (Photo 2) did not remove the problem with dominant and subordinate cows competing for feed. Creating the system, the company "BioControl" was probably not taking into account needs for splitting animals in smaller groups with different feeding regimes and access hours.

Looking at the issue of pasture management and organization of paddocks, one of the possible ways for future changes is planning the paddock lay-out and entrances to further facilitate for the cows to easily find her way out to the pasture area. Having two fields – production (on smaller paddocks) and the exercise paddock close to each other could improve cow's will to go out and exclude possible problems from walking long distances by achieving higher levels of synchronization within groups. However, with increased synchronization, the cows on the two treatments will influence each other. In that situation, cows on the two treatments cannot be compared in a scientifically correct way and the experimental results may be biased.

The synchronization between animals within a group has already been brought up as a problematic methodological issue for grazing studies as it has been proposed that cows grazing together cannot be treated as independent observations due to the synchronization between animals in a treatment groups on pasture (Fraser and Matthews, 1997).

Photo 1.

Photo 2.

This issue has been discussed but is unresolved, and especially in grazing experiments in AM barns it is almost impossible to organize several completely independent treatment groups as the cows must be able to move freely between the barn and pasture during grazing hours. The only solution to this problem would be to have two identical but separate AM barns and impose one treatment in each barn. This, however, is very costly and therefore it lies out of reach at the moment.

Conclusion

Part time grazing could be combined with automatic milking systems which will provide animals with natural environment and maintain appropriate number of visits to the milking unit. Production levels are highly dependent on supplementary feeding and weather conditions predetermining pasture quantity and quality. One of the crucial moments in the management of “AMS+pasture” systems is the appliance of well-functioning cow-traffic model which will create good flow of animals and consider effects of social facilitation in the herd. Further research in cows’ behaviour and motivation is needed to understand preference between indoor and outdoor environments.

Photos. Grazing season 2012:

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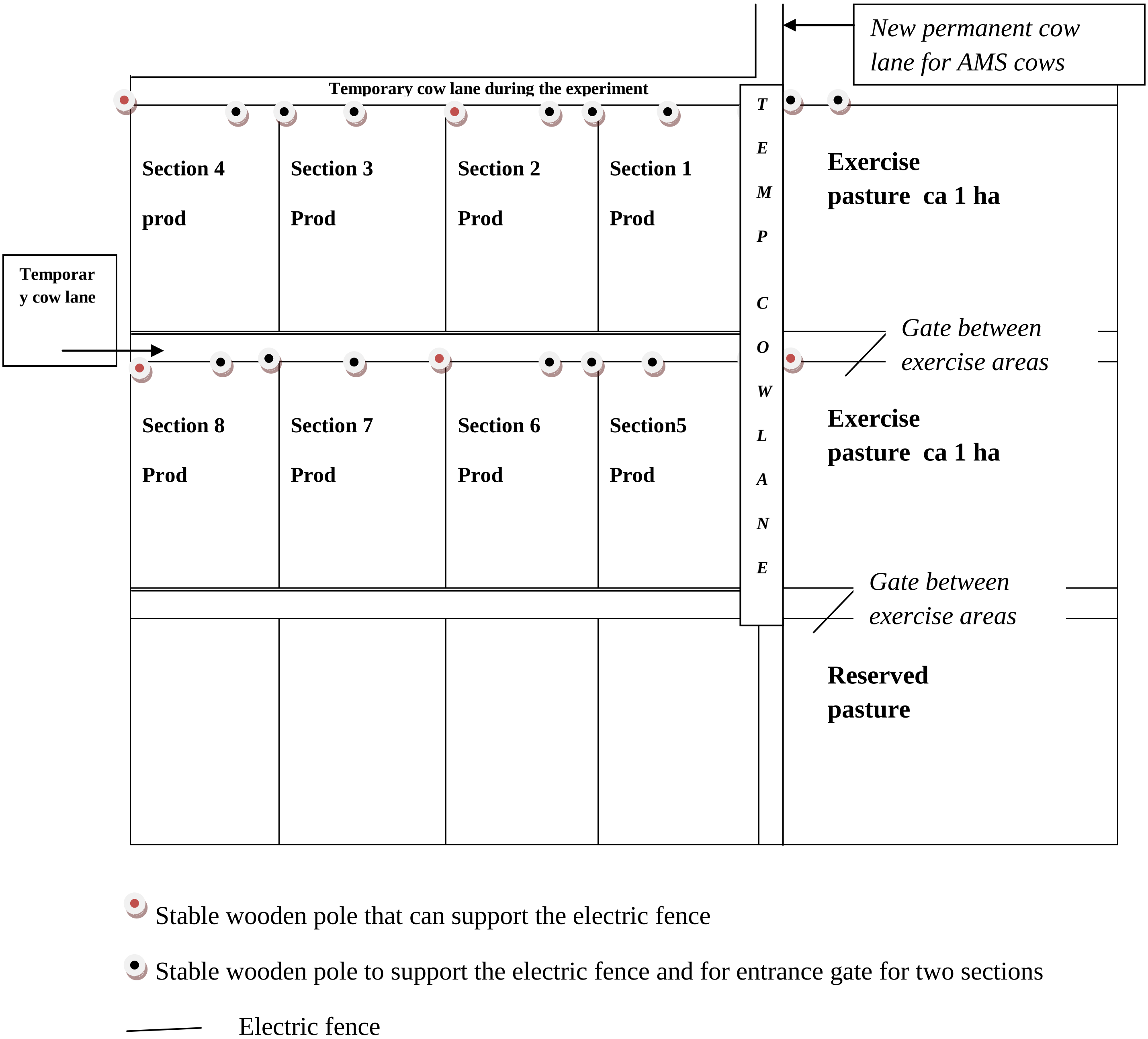
Appendix 1.

TOTFODER Betesförsök 2012 Solid 620

Led	Ex(A)	Prod(B)	A	B	A	B	A	B	A	B	A	B
ECM	43	43	39	39	35	35	31	31	27	27	23	23
Ensilage	11	7	11	7	11	7	11	7	12	8	13	9
Bete	1	5	1	5	1	5	1	5	1	5	1	5
Solid 620	14,5	14,5	12,7	12,7	10,7	10,7	8,8	8,8	6	6	3,2	3,2

Tot kg ts	25	25	23	23	21	21	20	20	18	18	17	17
MJ/kg ts	12	12	12	12	12	12	12	12	12	12	11	11
AAT/MJ	8	8	8	8	8	8	8	8	7	8	7	7
PBV, g	606	622	602	618	599	615	595	611	639	655	682	698
% av MJ	100	101	101	101	101	101	101	101	101	101	101	102
% av AAT	105	107	105	107	103	105	102	104	99	101	95	97
% rp	11	14	10	13	10	13	9	13	7	11	5	10
% grf	48	48	52	52	56	56	61	61	71	71	83	83
% NDF	40	40	41	40	42	41	43	42	45	44	48	47
% stärk	16	15	15	14	14	13	13	12	11	10	8	7
% av Ca	111	114	110	114	108	112	106	111	103	107	86	86
% av P	124	123	124	123	123	121	122	120	120	118	104	93
% bete	4	20	4	22	5	23	5	25	5	27	6	30

Appendix 2. Detailed plan of the pasture area



Appendix 3. Ethogram

Behavior	**Definition**
Standing	Standing up on all four legs
Lying down	Lying down on the ground
Grazing	Standing or walking while keeping the head at ground level, collecting grass with the tongue and performing constant jaw movements
Ruminating	Regurgitating feed mass, then chewing and swallowing it
Other	All other behaviours which do not involve grazing or ruminating

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