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GRAZING: AN ANIMAL WELFARE ISSUE FOR AUTOMATIC MILKING FARMS

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Background

In many countries, freedom of movement for animals outdoors in the summertime is important for animal welfare and grazing is a part of the concept in many cases. The Swedish Farm Animal Welfare Ordinance (SJVFS, 1988) stipulates that heifers and dairy cows shall be on pasture during the summer season. It further stipulates that the daily outdoor period shall include the hours between two milkings at the minimum. The ordinance is aimed at animal health and welfare, but ethical considerations and public opinion played important roles when the ordinance was instituted. Pasture offers an opportunity for animals to exercise, to strengthen hoofs and legs and to manifest a natural feed-searching and feed intake behaviour. Due to tradition, climatic conditions and herd structure, grazing of cows differs greatly throughout the world.

It has been shown that exercise has a favourable effect on animal health. In a long-term experiment with tethered cows, exercise decreased the number of veterinary treatments and the occurrence of non-infectious hoof and leg disorders (Gustafson, 1993). Although it is difficult to compare the effects in a tethered system with a loose house system, it seems probable that there is a favourable effect of extra exercise also in a loose house system. Herlin and Drevemo (1996) have studied the locomotion of dairy cows in different management systems by means of high-speed cinematography and kinematic analysis. They found that cows kept in free stalls with slatted floors the year around for an extended time period (2.5 years in the study) moved in a different manner compared with cows on pasture for 3 months every year. Measurements were taken at the end of the grazing period. The cows permanently housed indoors had a smaller maximum elbow joint angle and the hock joint angle was less flexed during the stance phase compared to cows on pasture. The minimum angle during the swing phase was greater in the indoor cows compared to the cows on pasture. The latter had a less pronounced flexion of the fetlock joint during the stance than cows kept indoors. In an experiment by Redbo (1990), a decrease in the frequency of stereotopies was observed when heifers were put out to pasture. This indicates that pasture is good for animal welfare. Another small factor that indicates a sense of well being on pasture is the observation that cows are seen lying down, stretched out on one side at pasture. This is not possible in the indoor cubicles (Stefanowska & Ipema, 2000).

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In addition to issues related to animal welfare, there is a public desire to preserve an open landscape with grazing cattle to preserve biodiversity and to retain the valued beauty of open areas. (Mathijs, 2000). It has also been proposed that cows disappearing from the meadows in summertime could endanger consumer acceptance of robotic milking (Mathijs, 2000).

Although grazing may be considered important to animal welfare and public acceptance it has been regarded to have practical and economical drawbacks when combined with AMS (automatic milking system) (Parsons & Mottram, 2000). However, in some surveys no substantial differences in milking frequency and milk yield between the pasture season and the indoor period were observed (Jagtenberg & van Lent, 2000a,b,c; van ´t Land *et al*., 2000). In these surveys large variations between herds have been found which imply that there is still much room for improvement.

Grazing and Cow Traffic

Well functioning cow traffic is an important part of successful robotic milking. During the grazing period, the organisation of cow traffic is perhaps even more important even though cows have access to more space. This is due to the longer distances to and from pasture, and that cow behaviour often seems to become more synchronised during the pasture season compared with the indoor period. Ketelaar-de Lauwere *et al.* (1999) observed that automatically milked cows at pasture synchronised their movements returning to the barn. The cows often returned to the barn in groups or in close succession. Likewise, they often walked from the barn to the pasture together with at least one other cow. In this manner many animals returned to the barn to be milked at the same time. A bottleneck may be caused on farms with many cows where the animals must wait while the milking unit is occupied. At other times of the day the milking unit will stand idle.

Free or forced cow traffic can be applied during the grazing period. From the results of several experiments with automatic milking, Ketelaar-de Lauwere (1999) concluded that free cow traffic gave too few visits to the milking unit while forced cow traffic was undesirable for animal welfare. The latter appeared to restrict cows' behaviour in a number of ways. The situation during the grazing period differs when two areas for feeding are available, pasture and indoor feeding. The question of free or forced cow traffic is therefore largely dependent on many factors such as the amount of pasture available, the distance to the pasture and the level of supplementary feeding in the barn.

One-way gates at the barn entrance and selection gates at the exit from the barn to the pasture have proved to be useful tools to control cow traffic during the pasture period. An alternative is to have a system where the exit to the pasture can be reached only after passing the milking unit. These measures may limit the number of animals that need to be fetched for milking as only recently milked cows will be able to leave the barn (Jagtenberg & van Lent, 2000c).

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The results from a large survey covering 25 Dutch farms with robotic milking and grazing (Jagtenberg & van Lent, 2000a) indicate that there are advantages in designing the barn so that animals are led to pasture directly without the possibility of supplementary roughage feeding after milking. Instead, supplementary roughage is made accessible to the animals before milking. Cow traffic to pasture will be speedy with this barn design. It also seems to decrease the milking interval, as cows are stimulated to return to the barn from pasture when they have direct access to supplementary roughage.

The number of cows in the barn seems to have a large influence on milk production and milking frequency and this becomes even more evident during the pasture period as shown in Table 1 (Jagtenberg & van Lent, 2000b). On farms with lower number of animals per stall, milk production and milking frequency increased when animals were put out to pasture. In contrast, in the larger herds, milk production and milking frequency decreased during the first period on pasture.

Table 1. Milk production (kg/cow/day) and number of milkings per cow/day. Effect of pasture season and herd size in a single-stall system (Jagtenberg & van Lent, 2000b).

Cows per stall	10 days before pasturing		10-20 days after pasturing	
	Milk (kg)	No. of milkings	Milk, kg	No. of milkings
34-50	28.0	3.1	+ 1.6	+ 0.1
50-55	28.1	2.8	+ 0.9	- 0.1
55-60	26.3	2.8	+ 1.1	- 0.2
> = 60	26.8	2.5	- 0.4	- 0.2

Daily Grazing Hours

In the Dutch survey, the length of the daily grazing period varied between 5 and 24 hours per day on different farms (Jagtenberg & van Lent, 2000a). On approximately half the farms, the animals had access to the pasture for more than 15 hours per day. However, a period of gradual adaptation to pasture in the beginning of the season was practised by most farms (Jagtenberg & van Lent, 2000c). Ketelaar-de Lauwere *et al*. (1999) compared behaviour and milking frequency of automatically milked cows on three different treatments: zero grazing (G0), access to pasture for 12 hours (G12) and access to pasture for 24 hours (G24). The treatments were studied during five consecutive periods on a herd of 24 milking cows. Each period lasted 14 to 24 days. It was concluded that milking frequency was lower on treatment G24 compared with G12 and G0 (Table 2). When the animals were on the 24-hour grazing treatment, more time was spent in the barn during the day and the visits to the milking unit were more unevenly distributed over time. As the experiment was performed with a herd of only 24 animals, the observed uneven distribution of visits to the milking unit when animals had 24-hour access to the pasture may have even larger effects on milking frequencies in a normal herd size, due to longer waiting times in front of the milking unit.

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Table 2. Treatments with zero-grazing, 12 hours or 24 hours of access to grazing area in an automatic milking system. Effect on milking frequency and time budget of animals (Adapted from Ketelaar-de Lauwere *et al.*, 1999).

Production factors	Period 1 Zero grazing G0	Period 2 12 hours G12	Period 3 Zero grazing G0	Period 4 24 hours G24	Period 5 12 hours G12
Milking frequency	2.5[a]	2.8[b]	2.7[bd]	2.3[c]	2.6[d]
Behaviour, % of time					
Total lying time	47.1[a]	46.1[a]	47.5[a]	49.0[a]	45.8[a]
Lying in rest	2.3[a]	5.3[b]	3.6[c]	5.0[b]	3.4[c]
Eating[1)] 1st lactation	20.7[a]	25.5[b]*	23.0[c]	26.1[b]	26.4[b]
Older cows	15.8[a]	24.7[b]*	18.5[c]	23.7[b]	23.3[b]

1) Grazing and feeding indoors

[a b c d] Different superscripts indicate a significant difference between treatments ($p<0.01$).

* Indicates a significant difference between 1st lactation cows and older cows for a certain treatment and behavioural parameter.

In a Danish report based on data from three AMS herds with summertime grazing it was found that two of the three farms had lower milking frequencies during grazing in July compared with the period after grazing (Raun & Rasmussen, 2001). In spite of this, the analysis of the management economic consequences, on an annual basis, showed that the reduced feed expenses made grazing 12 hours economically favourable compared with having only an exercise pen. The alternative with 24-hour grazing was yet more economically favourable. The economic benefit of reduced feed expenses far outweighed the economical costs such as the lower milk yield and the expenses for extra working hours during the grazing season. When the economic model assumed that calving of cows were planned to take place only during the period August-March, thus avoiding very high producing cows during the pasture period, economic benefit of grazing was even higher.

Distance To Pasture

The distance between the barn and the pasture area has received a great deal of attention in discussions concerning the possibilities of successfully combining AMS with grazing. The effect of the distance to the pasture was studied by Ketelaar-de Lauwere *et al*. (2000). No differences were found, with regard to milking frequencies or total number of visits to the milking unit, when animals had a short distance to the pasture (about 150 m) compared with when the distance was longer, about 350 m (Table 3). Effects on milk production were not studied in this experiment. However, the animals visited the barn in closer succession when the pasture was further away and the time between these periods of frequent visits was longer. A tendency for cows to gradually adapt to longer distances was also observed and it was concluded that animals may need some extra time to become accustomed to longer distances. The animals in this experiment had access to the pasture area for 15 hours during the daytime and drinking water

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was supplied in the barn only. Supplementary maize silage was supplied at a high level (18 kg dry matter/cow and day). The effects of distance on animal behaviour was limited (Table 4).

Table 3. The effect of distance on production parameters.

Reference	Distance	Hours grazing	Milking frequency	Total AME visits	Milk yield, kg
Ketelaar-de Lauwere et al., 2000	To paddock centre:				-
	146-168 m	15	2.8	5.0-5.2[2)]	-
	355-360 m	15	2.8	5.0-5.1[2)]	-
Spörndly & Wredle, 2002	Min-max[1)]:				
	50-330 m	24	2.5[a]	6.1a [3)]	29[a]
	260-850 m	24	2.3[b]	4.9b [3)]	26[b]

[a b] values with different superscripts in the same column differ significantly (p<0.05)

1) Min = nearest point of paddock, Max = most distant point of paddock

2) Visits to automatic milking unit 3) Visits to the barn

In the earlier mentioned field study on 25 Dutch farms, the distance between the barn and the pasture varied from a few meters up to 1300 metres, the mean distance being 175 meters (Jagtenberg & van Lent, 2000a). In this survey, the distance up to about 400 metres between the barn and field had a limited effect on milk production (Jagtenberg & van Lent, 2000b). However, many farmers adjusted their management to different situations and longer distances could be combined with measures such as higher levels of supplementation in the barn, limiting the time cows had access to pasture or combining more distant fields with fields near home at different times of the day. A statistical analysis of the data revealed that the percentage of cows that had to be collected increased with the distance to the pasture (14% more cows per km) (Ruis-Heutninck *et al.* 2001). Data from four farms in the survey, which practised no collecting of cows, also showed that average milking frequency per cow decreased with distance to the pasture (0.18 less milkings per km).

Table 4. The effect of distance on cow behaviour when cows have 15 hours of access to pasture (adapted after Ketelaar-de Lauwere, 2000).

	Distance from barn to paddock centre			
% of time (24 h)	Period 1 146 m	Period 2 360 m	Period 3 355 m	Period 4 168 m
Total lying	47.5[c]	41.1[a]	39.7[a]	44.3[b]
Lying at pasture	20.4[b]	16.2[a]	16.6[a]	19.4[b]
Grazing	26.1[b]	28.4[c]	24.3[a]	28.7[c]

[a b c] Different superscripts indicate a significant difference between experimental periods (p<0.01).

Spörndly & Wredle (2002) studied the effect of distance on milk production, visiting frequency and live weight change in an experiment that lasted from mid May until the end of August.

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Behavioural observations were also made covering a total of seven diurnal cycles (Wredle, 2001; Wredle & Spörndly, 2002). In these studies two groups of animals, group N and group D, with different distances to the pasture (near or distant) were included. The distance between barn and pasture was 50 m for the N group and 260 m for the D group, while the distance to the most distant part of the paddock was 330 m and 850 m for groups N and D, respectively. Pasture was an important part of the diet for cows in both groups as supplementary feeding of roughage in the barn was limited to approximately 4 kg dry matter per cow and day. Throughout the summer, the animals grazing near the barn (group N) had a significantly higher milk yield, both as kg milk and as kg energy corrected milk, compared with the animals that grazed on the distant pasture (group D) (Table 3). Milking frequency and the total number of visits in the barn was also higher for the N group but only during the first part of the grazing season (until mid July), indicating that animals changed their behaviour during the season. Observations confirmed that there was a change in animal behaviour in the distant group as the grazing season progressed. During the first half of the pasture season, the animals in both groups grazed around 20% of the time. However, during the latter part of the season, animals in group D reduced their grazing time substantially (Table 5). Cows in the N group spent more time outdoors (66%) compared with the cows in group D(43%). The main difference in the time budget was that cows in group N preferred to lie down in the pasture while the cows in group D spent more time lying down in the barn (Table 5).

Weather, Season and Adaptation

The grazing season is characterised by constant changes in weather, pasture supply, pasture quality, daylight length etc. All these factors are known to influence animal behaviour and production and naturally these effects also apply to automatically milked cows at pasture. However, compared with conventional milking, cows at pasture with AMS have more freedom to respond to the varying conditions. Therefore it becomes more important to understand cow behaviour and how it is influenced by different factors. As mentioned earlier, changes in cow behaviour during the grazing season have been observed in experiments with grazing and AMS (Wredle & Spörndly, 2002). As the season progressed, cows on a pasture situated far from the barn (group D mentioned earlier) substantially decreased their grazing time. This may partly be a seasonal effect due to a higher intake of early season pasture, which is greater than late season pasture (Spörndly & Burstedt, 1996). It was also observed that cows in group D started to lie down and rest in the cow track towards the end of the season. This behaviour increases the risk of mastitis and avoidance measures should be taken (Table 5).

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Table 5. The effect of distance on cow behaviour when cows have 24 hours of access to pasture (adapted after Wredle, 2001).

	June – mid July (Period 1)		August (period 2)	
% of time	Near 50-330m[1)]	Distant 260-850m[1)]	Near 50-330m[1)]	Distant 260-850m[1)]
Total lying	43	43	45	45
Lying at pasture2)	35[a]	13[b]	41[a]	2[b]
Grazing	23	22	21[a]	10[b]

[a, b] Different superscripts for a behaviour within the same period shows significant differences between distances ($p<0.01$)

1) Distance to the nearest and the most distant part of the paddock
2) In August the distant group started to lie down in the cow track

In general, weather appears to greatly influence animal behaviour during the first weeks on pasture. Animals have been observed to return to the barn with the first drops of rain. As the season progresses animals adapt and become somewhat less sensitive to rainy weather and can remain on the pasture during shorter showers (Karlsson, 2001; Wredle, 2001). In general, cows have been observed to return to the barn at heavy rainfall (Ketelaar-de Lauwere et al., 1999) which maintains the sward and prevents trampling and poaching (Jagtenberg & van Lent, 2000c). Cows are kept indoors for longer time periods during rainy weather on many farms (Jagtenberg & van Lent, 2000a; Karlsson, 2001).

During hot, sunny weather, cows find the coolest places and spend most of their resting time there. On farms with well-ventilated buildings, cows may prefer to stay indoors. In general, the number of milkings can be maintained during periods of hot weather (25-30°C) (Jagtenberg & van Lent, 2000c).

Supplementary Feeding and Pasture Allowance

Milk production, milking frequency and live weight gain have been compared in experiments with automatically milked cows at pasture with low (0-4 kg dry matter/cow and day) or high (*ad libitum*) levels of supplementary roughage. The results showed that high levels of supplementary roughage did not increase milk production or milking frequency when pasture quantity was sufficient (Spörndly & Wredle, 2002). However, the importance of a high pasture allowance must be emphasised when there is a low level of supplementary feeding. In a similar experiment, conducted during a year with unfavourable weather conditions, pasture quantity was not sufficient for *ad libitum* pasture intake. In this experiment cows without supplementary roughage had a significantly lower milk production (5 kg milk/day) compared with cows that were supplemented (Spörndly, 2000).

Many farmers that combine AMS with grazing have a high level of supplementation in the barn and a fairly limited pasture area (Karlsson, 2001; Raun & Rasmussen, 2001). With a high level of supplementation and a very limited amount of pasture, cows are less motivated to leave the

barn. In these cases time spent outdoors can be as low as 15% and grazing activity almost zero (Karlsson, 2001). In the previously mentioned Dutch survey, supplementary feeding on different farms and on different occasions varied between 2.5-15 kg with an average of 7 kg dry matter roughage per cow and day (Jagtenberg & van Lent, 2000a).

In an experiment by Ketelaar-de Lauwere *et al.* (2000), the effect of sward height on milking frequency and animal behaviour was studied. Sward height in the experimental periods generally decreased from 11-12 cm to around 7-8 cm. As sward height decreased, animals spent more time in the barn and the number of visits in the automatic milking unit increased.
The level of supplementary roughage in the experiment was high.

The results of these experiments indicate that when pasture allowance is high, supplementary feeding can be minimised. A few units of automatic milking have been installed in areas where cows are entirely dependent on pasture the year around. Cow traffic is controlled by means of fencing systems, gates, concentrates in the milking unit, and sometimes water availability. Results from actual studies on these systems have not been found.

Fetching of Animals

The frequency of fetching cows for milking showed large differences. The percentage varied between 0 to over 90% on different Dutch farms (Jagtenberg & van Lent 2000c). A number of significant observations were made when this variation was studied. :

- Selection gates leading out to the pasture generally gave lower fetching percentages.
- Farmers that fetched cows around 4 p.m. had to fetch 63% of the animals while farmers that waited until evening (around 9 p.m.) only had to fetch 38% of the animals.
- Drinking water and supplementary feeding in the barn stimulated the cows to return from the pasture voluntarily.
- No clear relationship between fetching percentage and distance to the pasture was found but a certain increase in fetching percentage was observed when animals grazed on distant pastures.

It is especially interesting to note that farms with limited fetching had similar or slightly better milk production and milking frequencies compared with farms with more frequent fetching (Table 6).

Table 6. Production and milkings from limited or more frequent fetching (Jagtenberg & van Lent, 2000c).

	No of milkings	Net yield (kg milk)
Limited fetching	2.9	5385
More frequent fetching	2.8	4907

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Location of Drinking Water

An effective way to motivate the cows to return to the barn at regular intervals is to supply drinking water in the barn. This practice was used in the grazing experiments by Ketelaar-de Lauwere *et al.* (1999, 2000) and is also found on many AMS farms. In the experiment with different distances between barn and pasture by Spörndly & Wredle (2002), animals only had access to drinking water in the barn between May-July. In August however, the experimental animals on all treatments had access to drinking water both at pasture and in the barn. No changes in behaviour were observed that could be related to the change in water supply.

In a recently conducted experiment, the effect of supplying water in the pasture was studied. One group of animals was offered water in the barn only, while the other treatment group was offered water both in pasture and in the barn (Spörndly, unpublished). Animals in both groups grazed at a distance of 360 metres from the barn. Water consumption data from the experiment (covering 4 diurnal periods) showed that the animals in both groups drank the same amounts of water. Thus it was concluded that it seems to be sufficient for cattle grazing at distances up to approximately 400 metres to be supplied with water in the barn only. However, water supply is an important animal welfare issue and these conclusions are based on only one experiment.

Cow Tracks, Treading, Poaching and Pasture Damage.

The condition of cow tracks and the grazing sward are especially important in an AMS system as cows are expected to voluntarily walk to the pasture and back to the barn several times per day. The whole management system will be affected if the cow tracks are in a poor condition and animals may avoid walking. Sometimes cows get into the habit of resting on patches with bare earth (Karlsson, 2001). This can lead to dirty udders and problems with mastitis and therefore it is of great importance that management measures are taken to prevent this behaviour and that pastures are kept in a good condition.

Conclusions

Managing cows on pasture during the summer season is considered an important welfare issue in many countries. It contributes to improved health and wellbeing of the animals. Based on present limited information, the overall conclusion is that grazing can be integrated as part of management system including automatic milking of dairy cows. Research data and farm surveys have shown that systems for selecting cows leaving and entering the barn facilitate cow traffic and management. Drinking water and supplementary feeding in the barn stimulate the cows to return from the pasture voluntarily and at regular intervals. The cows shall preferably enter the barn individually or in small groups to avoid long waiting times at the entrance of the milking stall(s). Short distances between the barn and the pasture are preferable. A study conducted on three farms showed that 24-hour grazing systems resulted in lower milking frequency and lower yield compared with zero grazing or 12-hour grazing systems, but did not affected the economy due to lower feed costs. Long distances between the barn and the pasture generally affect milking

frequency and yield negatively. Long distances can also influence the behaviour of animals. It has also been observed that animals can change their behaviour during the grazing season. It is important that these changes in behaviour are observed at an early stage so that management measures can be taken to counteract unfavourable effects on production results and animal health.

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References

Gustafson, G.M. (1993). Effects of daily exercise on the health of tied dairy cows. Prev. Vet. Med. 17, 209-223.

Herlin, A.H. & S. Drevemo (1996). Investigating locomotion of dairy cows by use of high-speed cinematography. Paper presented at the 3rd International Workshop on Animal Locomotion in May 1996 in Saumur France. Equine vet. J. Suppl. 23, 106 – 109

Jagtenberg, K. & J. van Lent. (2000a). Access to pasture and the milking robot. Praktijkonderzoek 13 (2), 4-5.

Jagtenberg, K. & J. van Lent (2000b). Robotic milking and pasturing. Praktijkonderzoek 13 (3), 7-9.

LABOUR, ECONOMICS AND ANIMAL WELFARE

Jagtenberg, K. & J. van Lent (2000c). Cows go to and from the milking robot. Praktijkonderzoek 13 (6), 1-5.

Karlsson, M. (2001). Pasture management in automatic milking systems (AMS). A field study on three farms. (In Swedish with English summary) MSc report 150, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden, 39 pp.

Ketelaar-de Lauwere, C.C. (1999). Cow behaviour and managerial aspects of fully automatic milking in loose housing systems. Wageningen Agricultural University, The Netherlands, Thesis, 189 pp.

Ketelaar-de Lauwere, C.C., A.H. Ipema, E.N.J. van Ouwerkerk, M.M.W.B. Hendriks, J.H.M. Metz, J.P.T.M. Noordhuizen & W.G.P. Schouten (1999). Voluntary automatic milking in combination with grazing of dairy cows. Milking frequency and effects on behaviour. Applied Animal Behaviour Science 64:2, 91-109.

Ketelaar-de Lauwere, C.C., A.H. Ipema, C. Lokhorst, J.H.M. Metz, J.P.T.M. Noordhuizen, W.G.P. Schouten & A.C. Smits, (2000). Effect of sward height and distance between pasture and barn on cows' visits to an automatic milking system and other behaviour. Livestock Production Science 65:1-2, 131-142.

Mathijs, E. (2000). Public acceptance of robot milking. In: Robotic Milking, Eds. H. Hogeveen & A. Meijering, Proceedings of the international symposium 17-19 August 2000, Lelystad, The Netherlands, pp.243-247.

Parsons, D.J. & T.T.F. Mottram (2000). An assessment of herd management aspects of robotic milking on UK dairy farms. In: Robotic Milking, Eds. H. Hogeveen & A. Meijering, Proceedings of the international symposium 17-19 August 2000, Lelystad, The Netherlands, pp.212-220.

Raun, C. & M. D. Rasmussen (2001). The effects of grazing on milking frequency, milk yield and business economics in automatic milking systems. (In Danish with English summary). DJF – Rapport, Husdyrbrug No. 26, 106 pp, Danmarks Jorbruksforskning, Tjele, Denmark.

Redbo, I. (1990). Changes in duration and frequency of stereotypies and their adjoining behaviours in heifers before, during and after the grazing period. Appl. Anim. Behav. Sci. 26, 57-67.

Ruis-Heutinck, L.F.M., H.J.C. van Dooren, A.J.H. van Lent, C.J. Jagtenberg & H. Hogeveen (2001). Automatic milking in combination with grazing on dairy farms in The Netherlands. Proceedings of the 35th Congress of the Internaional Society of Applied Ethology, 4-8 August 2001, Davis, USA. (In preperation).

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SJVFS (1988). Statue order on animal welfare (Djurskyddsforordningen) SFS 1988:539. Jonkoping, Sweden.

Spörndly, E. (2000). Pasture with high or low level of supplementary feeding in an automatic milking system (AMS) (In Swedish). In: KungsängenDagarna. Ed. R. Spörndly. Report 248, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden, pp.37-42.

Spörndly, E. & E. Burstedt (1996). Effects of sward height and season on herbage intake of strip-grazed dairy cows. Acta Agric. Scand. Sect. A. Animal Sci. 46, 87-96.

Spörndly, E. & E. Wredle (2002). The effect of distance to pasture and level of supplementary feeding on visiting frequency, milk production and live weight of cows in an automatic milking system. Proceedings of the First North American Conference On Robotic Milking. Toronto, Canada, March 2002. Poster presentation.

Stefanowska, J. & A.H. Ipema (2000). Effect of access to a field on the visiting pattern of cows to the automatic milking system and other behaviour. In: Robotic Milking, Eds. H. Hogeveen & A. Meijering, Proceedings of the international symposium 17-19 August 2000, Lelystad, The Netherlands, pp.194-195.

Van ´t Land, A., A.C. van Lenteren, E. Van Schooten, C. Bouwmans, D.J. Gravesteyn, & P Hink (2000). Effects of husbandry systems on the efficiency and optimisation of robotic milking performance and management. In: Robotic Milking, Eds. H. Hogeveen & A. Meijering, Proceedings of the international symposium 17-19 August 2000, Lelystad, The Netherlands, pp. 167-176.

Wredle, E. (2001). Grazing in automatic milking system – Effect of distance between pasture and barn and different levels of supplementary feeding on cow's behaviour. (In Swedish with English summary.) MSc report 143, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden, 31pp.

Wredle, E. & E. Spörndly (2002). Grazing combined with automatic milking systems. Effect of distance to pasture and level of supplementary feeding on cow's behaviour. Proceedings of the First North American Conference On Robotic Milking. Toronto, Canada, March 2002. Poster presentation.

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