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Swedish University of Agricultural Sciences

Faculty of Veterinary Medicine and Animal Sciences

Production and management in automatic milking systems

Produktion och skötsel i automatiska mjölkningssystem

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Abstract

Different cow traffic systems are used to guide the dairy cows to make them pass the milking unit in automatic milking systems (AMS). Several studies have compared milk production in different cow traffic systems but there were little evidence that one system has a higher production than another. It is likely to believe that the farmers' management, engagement and dedication have greater importance. Therefore, this study investigated which factors affect milk production in AMS. The study consisted of a literature study, a questionnaire sent out to Swedish dairy farmers with AMS, collection of key figures from the participating farmers' management software and six interviews with selected dairy farmers who were successful in their production. Results from the questionnaire were compared to production variables from the management software. Milk production was defined as milk per milking unit and day (MPu) and milk per cow and day (MPc). It was found that traffic system had no impact on milk production and it was rather the farmers' management that had importance. Farms feeding partly mixed ration (PMR) had greater MPu (113 kg higher, $p<0.05$) and a tendency for greater MPc (1.4 kg higher, $p<0.1$) and less time unoccupied in the milking unit (4.5 percentage points lower, $p<0.05$) compared to farms feeding only roughage in the feed bunk. Farms with high part of Jersey cows milked in AMS had lower MPc (0.08 kg lower per each extra percentage point of Jersey, $p< 0.01$) and a tendency for lower MPu (3 kg lower per each extra percentage point of Jersey, $p<0.1$). Farms with high bulk tank somatic cell count (SCC >250) had both lower MPu (227 kg lower, $p<0.001$) and MPc (3 kg lower, $p<0.01$) compared to farms with SCC ≤250. Number of cows fetched to the milking unit had no effect on MPu or MPc. However, it seems important to fetch selected cows that do not milk voluntary. Farms with slatted floors had lower MPu (127 kg lower, $p<0.05$), MPc (3 kg lower, $p<0.05$) and more time unoccupied in the milking unit (4.5 percentage points higher, $p<0.05$) compared to farms with solid floor.

Sammanfattning

Olika kotrafiksystem används för att få mjölkkor att passera roboten regelbundet i automatiska mjölkningssystem (AMS). Tidigare studier har inte kunnat påvisa någon tydlig skillnad i mjölkproduktion mellan olika trafiksystem. Det är troligt att lantbrukarens skötsel, intresse och engagemang har större betydelse för produktionen. Denna studie undersökte därför vilka faktorer som påverkar mjölkproduktion in AMS. Studien bestod av en litteraturstudie, en enkät som skickades ut till mjölkbönder med AMS, insamling av nyckeltal från de deltagande gårdarnas driftledningsprogram samt sex intervjuer med utvalda gårdar som lyckats nå hög mjölkproduktion. Resultatet från enkäten jämfördes med produktionsvariabler från driftledningsprogrammet. Mjölkproduktion definierades som mjölk per mjölkningsenhet och dag (MPu) och mjölk per ko och dag (MPc). Det visade sig att trafiksystem hade liten eller ingen påverkan på mjölkproduktionen, utan det var snarare lantbrukarens skötsel som hade betydelse. Gårdar som utfodrade med blandfoder hade högre MPu (113 kg högre, $p<0.05$), tendens för högre MPc (medel 1.4 kg högre, $p<0.1$) och mindre tid som mjölkningsenheten stod oanvänd (4.5 procentenheter lägre, $p<0.05$) jämfört med gårdar som utfodrade med endast grovfoder på foderbordet. Gårdar med hög andel Jerseykor som mjölkades i AMS hade lägre MPc (0.08 kg lägre per varje extra procentenhet av Jersey, $p<0.01$) och en tendens till lägre MPu (3 kg lägre per varje extra procentenhet Jersey, $p<0.1$). Gårdar med högt tankcelltal (SCC >250) hade både lägre MPu (227 kg lägre, $p<0.001$) och lägre MPc (3 kg lägre, $p<0.01$) jämfört med gårdar med SCC ≤250. Antal kor som hämtades till roboten hade ingen betydelse för MPu eller MPc. Hursomhelst verkar det viktigt att hämta utvalda kor som inte mjölkar sig frivilligt. Gårdar med spaltgolv hade lägre MPu (127 kg lägre, $p<0.05$), lägre MPc (3 kg lägre, $p<0.001$) samt mer tid som roboten stod oanvänd (4.5 procentenheter högre, $p<0.05$) jämfört med gårdar med fast golv.

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Contents

Introduction

Automatic milking systems give an opportunity for dairy farmers to reduce labor cost since the cows visit the milking unit voluntarily to be milked (Svennersten-Sjaunja & Pettersson, 2008). It is also an opportunity to increase milk production per cow since it is possible to increase the milking frequency (i.e. number of milkings) per cow and day without need for extra labor. Studies have shown that increased milking frequency can increase milk production by up to 10.4 % when milking cows three times per day compared to two (Klei et al., 1997; Hogeveen et al., 2001; Melin et al., 2005). Milking frequency is dependent of the cows' willingness to voluntary visit the milking unit continuously during the day (Melin et al., 2005). However, cows own motivation to be milked is low (Prescott et al., 1998), which makes management strategies and barn layout important in AMS.

Different cow traffic systems are used to make the cows regularly pass the milking unit. The term cow traffic refers to the cows' movement in the barn to satisfy their needs such as feeding, resting and milking (Forsberg, 2008). Different gate systems are used to divide the barn in different sections. Depending on the traffic system used, the cow movement can partly be controlled by the farmer. The main reason for cows to visit the milking unit is their motivation to receive concentrate feed and this is therefore the most common approach to establish movement in AMS (Prescott et al., 1998; Halachmi et al., 2000). However, the need for feeding roughage and resting is also used to make the cows pass the milking unit (Hermans et al., 2003; Ketelaar de- Lauwere et al., 1996; Bach et al. 2009).

The automatic milking unit measures parameters such as milk yield and conductivity that allows farmers to predict changes in health status earlier, taking the right actions (Jacobs and Siegford, 2012). It makes it possible to control the herd down to the smallest production unit, each individual cow (Maltz, 2000). It also allows the farmer to set milking intervals and adjusting concentrate rations for both individual cows as well as on heard level. There is a lot of information available, but in order to take advantage of the capacity of each milking unit other skills are needed compared to conventional milking (Jacobs and Siegford, 2012). To establish a profitable production each milking unit must have a high occupation rate **(OR)**, i.e. the time the milking unit is used for milking per day (André et al., 2010). The cows must continuously visit the milking unit during the day in order to achieve a high OR. There is need for an animal flow where the cows are circulating and you are looking for an evenly distributed cow density in the barn at all times (Winter & Hillerton, 1995). Each cow must be able to be milked at least 2-3 times per day (de Koning & Ouweltjes, 2000), which means that there cannot be too many cows served by the same milking unit.

However, several studies have compared different cow traffic systems but there is little evidence that one system has a higher production, or is more efficient than the other. Svennersten-Sjaunja & Pettersson (2008) concluded that the management routines were of importance to succeed in AMS. In a study investigating efficiency of the milking unit it was concluded that farm management should focus on cow management, feeding, housing conditions and animal health (de Koning & Ouweltjes, 2000). Other studies have concluded that the efficiency of the milking unit can be improved by e.g. different placing of concentrate feeders, settings of milking intervals, setting of minimum milk flow etc. (Besier and Bruckmeier, 2016; Gygax et al., 2007; Stefanowska et al., 1999b). There is reason to think that the milk production is not depending on traffic system, but rather a combination of various management factors within each traffic system.

The objective of this study was to investigate which management factors affect production on farms with automatic milking. The hypothesis was that feeding strategy, barn layout, traffic system and the farmers' dedication and interest are affecting the production in AMS farms.

Literature review

The literature review will summarize what is currently known about cow traffic systems, barn layout, feeding and management factors and its relation to milk production in AMS. Decreased udder health has a great impact on milk production (Seegers, 2003), which makes it necessary to take udder health aspect in consideration when formulating advise about management. Therefore, this literature review will also make a brief review of current research concerning udder health management factors in AMS.

Cow traffic system

There are several cow traffic solutions with different degree of control of the cows' movement: feed first, milk first, forced traffic and free traffic with and without waiting area. The willingness of the cow to fulfill her needs, such as eating and resting, is used to establish movement in the barn. This movement is organized with selection gates and one-way gates. Cows' motivation to be milked is low, but by providing concentrate feed in the milking unit, movement can be established and the visit becomes more attractive (Prescott et al., 1998; Halachmi et al., 2000). One-way gates are navigating the cows through the barn in one direction. Selection gates are programmed to decide whether the cows have permission to be milked or not and subsequently direct the cows to the milking unit or another section of the barn (Hermans et al., 2003). Milking permission is based on criteria set by the farmer to achieve the desired milking interval. These criteria are usually based on time since last milking, expected milk yield or how well the cows succeeded in the previous milking. If the previous milking was not completed for some reason (e.g. due to of failure during teat cup attachment or if the cow kicked off the teat cups), she can receive a new milking permission immediately after exiting the milking unit and she will be selected for milking the next time she visits the milking unit or selection gate (Lyons et al., 2015; Bach et al., 2009).

Feed first

There are different definitions of feed first internationally compared to Sweden. This study is based on the Swedish definition, which says that in feed first the cows have free access to roughage and can move freely from the cubicle area to the roughage area. By this definition there are two types of feed first:

1) Cubicle area and roughage area are separated from each other, however a few cubicles can be situated in the roughage area. The cow is free to move from the cubicle area to the roughage area through one-way gates at any time. To get back to the cubicles after feeding, the cow must pass through a selection gate. If the cow has milking permission she will be sorted into the waiting area in front of the milking unit. If she does not have milking permission she will be sorted into either the cubicle area, or to a separate pen with concentrate feeders, depending on the barn layout.
2) Cubicle area and feeding area is one united pen where the cows are free to move from the cubicles to the roughage area and back. To get access to concentrate feeders, the cow must pass a selection gate. If the cow has milking permission she will be sorted into the waiting area in front of the milking unit. If she does not have milking permission she will be sorted into a separate pen with concentrate feeders.

Milk first

The cows are free to move from the roughage area to the cubicles through one-way gates. To get access to the roughage area from the cubicle area the cow must pass a selection gate. If the cow has milking permission she will be sorted into the waiting area in front of the milking unit. If the cow does not have milking permission she will be sorted to the roughage area.

Free traffic

In a free traffic system the cows can move freely between the roughage area and the cubicle area. The cows are provided with concentrate feed inside the milking unit, which motivate them to go there in order to be milked. Free traffic systems can be fitted either with or without waiting area in front of the milking unit. If there is a waiting area in front of the milking unit, the cows enter it through a one-way gate. No selection gates occur in this system.

Forced traffic

Cows are free to move from the roughage area to the cubicle area through one-way gates. To access the feeding area again, the cows must pass through the milking unit. If the cow has milking permission she will be supplied with concentrate and she will be milked. If she does not have permission to be milked, the exit gate will open and no concentrate will be delivered (Bach et al., 2009).

Efficiency of the milking unit

The efficiency of the milking unit is dependent on many factors, e.g. milk yield, milking frequency, milking intervals, success of teat cup attachment and duration of milking procedure (Gygax et al., 2007). It can be measured in occupation rate (OC), i.e. the proportion of time used for milking per 24 h. It is not possible to reach 100 % occupation rate, because some of the time has to be used for cleaning of the milking unit. However, an occupation rate of 90 % is possible to reach (Castro et al., 2012). Sitkowska et al. (2015) found a positive correlation between milking duration and milk yield, and also between milking duration and milk flow rate. Therefor they concluded that it is important to monitor these parameters carefully. Castro et al. (2012) found that milk yield per milking unit is highly dependent on the number of cows and their milk flow rate. Even though cows prefer to be active during daytime and to rest during night, studies have shown that visits to the milking unit tend to be equally spread over the day and night. However, there are fewer visits early in the morning when many of the cows are laying down. This pattern was independent of traffic system (Munksgaard et al., 2011; Stefanowska et al., 1999b).

The time cows spend in the milking unit without being milked (i.e. non-milking visits, entering and exiting) should be as short as possible to maximize the efficiency of the robot. Halachmi et al. (2000) found that the mean duration in the milking unit was 8.8 min for cows that were milked, and for cows that do not have milking permission it took less then four minutes to pass the milking unit. Gygax et al. (2007) reported a mean milking time of 7.6 minutes during a normal milking. When milking failed (i.e. one or more teat could not be found by the robotic arm or the teat cup were kicked of early in the milking), the median time to pass the milking unit was 6.3 and 7.8 minutes for free and milk first traffic respectively. Stefanowska et al. (1999a) showed that cows that had to stop outside the milking unit, because it was occupied, had a slower walking speed when entering the milking unit.

Stefanowska et al. (1999b) observed that cows hesitated more before entering the milking unit if the previous visit was a non-milking visit (i.e. the cows were not milked and did not receive concentrate).

Holding area is an open space between the cubicles and the AMS, which allows the cows enough space to wait before entering and after exiting the milking unit. These are used to reduce the social interaction between cows and create efficient traffic flow to and from the milking unit (Jacobs et al., 2012). Cows linger more in the milking unit after non-milking visits and milking failures (Stefanowska et al., 1999a and 1999b; Jacobs et al., 2012). These visits also created confusion and aggression, because the cows did not receive concentrate or the concentrate was taken away before they had finished. These cows tended to block the one-way exit after the milking unit and prevented other cows to exit after milking. The milking unit was therefore blocked until the cows had moved away (Stefanowska et al., 1999b; Jacobs et al., 2012). Jacobs et al. (2012) found a positive relationship between the number of cows in the holding area (i.e. the area outside the one-way exit gate and the adjacent waiting area in front of the milking unit) and the duration of hesitation before exiting through the exit gate. Stefanowska et al. (1999b) saw that cows in general spend more time in the exiting area than the entry area. They argued that the concentrate that is offered in the milking unit motivated the cows to enter. When the cows should exit the milking unit there was no reward that motivated them to leave. They argued that one way to get around this was to offer concentrate outside the exit area as well.

Tremblay et al. (2016) found that old farms fitted with AMS on average reach the same production level after two years, compared to newly built farms fitted with AMS. The first four years after installation of AMS in old farms was associated with lower production compared to the production more than four years after installation. This was explained by that old farms fitted with AMS must often adapt old cows to the new milking system, while new built farms had a higher grade of replacement heifers that were adapting faster to the system. The production of milk per milking unit and day were lower in a pen with one milking unit compared with two milking units per pen. This was explained by the all time access of the milking units. If one milking unit were washing the other could still be active, which made it easier for low ranked cows to access the milking unit.

Settings in the milking unit

Settings in the milking unit are important for the udder health, production and efficiency. A higher vacuum level in the milking machine can increase milk flow rate and thereby decrease milking time for each cow. However, Barkema et al. (1999) found an increase in teat end callosity and prevalence of intra mammary infection with increased milking machine vacuum. Mein (2012) argued that an optimal vacuum level was 38±2 kPa and that only about 20 % of new udder infections depended directly or indirectly on the milking machine.

Besier and Bruckmeier (2016) found that a higher vacuum level during milking made the teat wall thicker, especially in the end of milking. By early removal of the teat cups at the end of milking, teat damage could be reduced. Removal of the teat cups at a milk flow up to 600 g/min did not markedly reduce milk yield but could reduce machine on time and thereby reduce the teat end damage at the end of milking. Jago et al. (2010) found that when teat cups were removed at 400 g/min **(MF400)** compared to 200 g/min **(MF200)** the milking time could be reduced by 0.75-0.92 min/cow. When the eat cups were removed at 0.2 kg/min or after a maximum time of 7.5 (a.m. milking) or 5.4 (p.m. milking) which ever came first, the milking time was reduced by 1.121.29 min/cow compared to MF200 before peak lactation. After peak lactation, the difference was reduced to only 0.5 min/cow and milking. There were no difference in milk production between the treatments and there were no clear evidence that it resulted in higher SCC.

Milking intervals

Shorter milking intervals have been shown to increase milk production and reduce somatic cell count (**SCC**) in dairy cows (Klei et al., 1997; Melin et al., 2005; Wright et al., 2013). AMS allows the herd manager to set shorter milking intervals for the cows without the need for extra labour. However, the cows must voluntarily visit the milking unit in order to attain the desired amount of milkings per day (Melin et al., 2005). Melin et al. (2005) studied two different settings of milking intervals in the selection gate: 4 hour intervals (**MI4**) with a theoretical maximum of six milkings per day, and 8 hour intervals (**MI8**) with a theoretical maximum of three milkings per day. The attained number of milkings per day was 3.2 for MI4 and 2.3 for MI8. This indicates that milking interval settings had an impact on the number of milkings. However, the MI4 group was far from the theoretical maximum of 6 milkings per day. This might be explained by the open waiting area, which made it possible for the cow to return to the cubicles when not allowed to enter the roughage area.

Sitkowska et al. (2015) found the optimal number of milkings per cow and day to be 2.6-2.8 with a milk flow rate of 2.6 kg/min. de Koning & Ouwektjes (2000) evaluated the relationship between number of milkings per day and milk yield per milking unit and day. They found that short milking interval results in lower milk yield per milking and increased number of milkings per day. Increased milk yield per milking resulted in less milkings per day but a higher milk production per milking unit and day. However, the cows should be prevented from decreasing below two milkings per day. They made a model to calculate possible number of milkings per milking unit, with the assumption that occupation rate (OC) do not depend on average yield or flow rate.

*Possible number of milkings per day = (OC * 1440)/time per milking visit*

Stefanowska et al. (1999a) found that cows in milk first had milking intervals that were on average 2 h shorter than in free traffic and feed first type 2 (i.e. where the cows could move freely between cubicle area and roughage area and vice-versa). Bach et al. (2009) found that the number of voluntary visits and non-milking visits to the milking unit was greater in forced traffic compared to free traffic. The cows had to pass the milking unit to get feed and water and they argued that this explained the difference. Stefanowska et al. (1999a) argued that to establish enough traffic through the selection gate, the cows should be rewarded each time they passed, not only when selected to milking. For example by placing a treat after the selection gate in the area where the cows are directed when not selected to milking.

The type of visit in the milking unit had an impact on the cows' behavior when leaving the milking unit. Cows that were successfully milked had more complete routine cycles, which means that the cows both ate and rest before the next visit to the milking unit. Cows that are unsuccessfully milked or do not have milking permission tended to have shorter intervals between the visits (Ketelaar-de Lauwere et al., 2000; Stefanowska et al., 1999b; Jacobs et al., 2012; Bach et al., 2009). Too short intervals between the visits were a disadvantage for the capacity of the milking unit. Too many visits in the milking unit will lead to more non-milking visits, which will decrease occupation rate in the milking unit (Ketelaar-de Lauwere et al., 2000).

Milk production

Shorter milking intervals, i.e. more milkings per day, have been shown to increase milk production in lactating cows (Klei et al., 1997; Melin et al., 2005; Wright et al., 2013). According to Stelwagen (2001), milk production can increase by 7-32 % for cows milked three times per day compared to cows milked two times per day. More frequent milking during the first weeks of lactation was also associated with higher production during the rest of the lactation, especially in primiparous cows (Dahl et al., 2004; Bar-Pelled et al., 1995; Wright et al., 2013). On the other hand, longer milking intervals where the cows were milked once daily, reduced milk production by 7-40 %, depending on factors such as parity, breed and stage of lactation (Stelwagen et al., 2013).

Bach et al. (2009) found that the number of milkings was greater in forced traffic compared to free traffic. However, there was no difference in milk production between the systems. Hermans et al. (2003) found that there was no difference in the number of milking visits in forced traffic compared to forced traffic where 1/3 of the feed bunk were accessible from the cubicle area. There was no difference in milk production when corrected for stage of lactation. However, there tended to be more non-milking visits in forced traffic. Both Hermans et al. (2003) and Bach et al. (2009) argued that cows in forced traffic are more motivated to pass the milking unit because it is necessary in order to get roughage compared to free traffic and forced traffic with access to part of the feeding table. Munskgaard et al. (2011) on the other hand found no difference, neither in number of milkings, non-milking visits or in milk production, when comparing forced and free traffic (see table 1). To the author's knowledge, there were no studies investigating the effect of feed first on milk production.

Milking failure means that the robotic arm fails to locate one teat, which results in one or more udder quarters that are not emptied. This means prolonged milking intervals in the affected udder quarters. In a study by Bach and Busto (2005), 7.6 % of all milkings failed. It was most common that the robotic arm found all teats when cleaning, but was not able to locate one or more teat when attaching the teat cups for milking. The milk production was greater in the affected teat after an attachment failure. However, when accounting for the increased milking interval for the individual teat after a failure, it resulted in a reduction in milk production by 26 % in the following milking. Milk production in the other, unaffected teats, was also reduced while milked at the same time as attachment failure in one teat. Cows in later lactation declined more in production than cows in early lactation. However, missing one teat occasionally did not affect milk production in long term, it was only a problem if it occurred too frequently.

Table 1. Milk production, milking frequency, and total number of visits in different traffic systems

Reference	Traffic system	Milk production (kg/ cow and day)	No. of milkings visits	No. of non-milking visits	Total number of visits
Gygax et al. (2007)	Milk first	–	2.4	–	–
Melin et al. (2005)	Milk first*	31.5	2.6	2.0	4.6
Average	**Milk first**	**31.5**	**2.5**	**2.0**	**4.6**
Bach et al. (2009)	Free	30.9	2.5	–	–
Castro et al. (2012)	Free	–	2.7	–	–
Gygax et al. (2007)	Free	–	2.5	–	–
Munksgaard et al. (2011)	Free	24.6	3.2	2.1	5.3
Deming et al. (2013)	Free	34.7	2.6	–	–
Average	**Free traffic**	**30.1**	**2.7**	**2.1**	**5.3**
Bach et al. (2009)	Forced	29.8	2.4	–	–
Hermans et al. (2003)	Forced	28	2.8	2.2	5.1
Munksgaard et al. (2011)	Forced	24	3.2	1.9	5.1
Average	**Forced traffic**	**27.3**	**2.8**	**2.1**	**5.1**
Hermans et al. (2003)	Forced w/ partly free roughage	25.8	2.8	1.9	4.8

*In this study the effect of different settings for milking interval was tested which might have an impact on the result. The numbers are calculated averages of the two treatments based on numbers published in the study.

Udder health

Studies have shown that increased milking frequency has a positive effect on udder health, with a reduction in SCC (Klei et al., 1997; Melin et al., 2005; Wright et al., 2013; Ouweltjes et al., 2007; Dahl et al., 2004). Dahl et al. (2004) also showed that increased milking frequency in early lactation had a tendency of a reducing effect on SCC during the entire lactation. However, Stelwagen et al. (2013) did not see any difference in mastitis prevalence when comparing two and three milkings per day, although individual cows had an increased SCC with longer milking intervals. Hovinen and Pyörälä (2011) concluded that irregular milking intervals led to higher somatic cell count and also that too long or too short milking intervals was detrimental to the udder. This supports the results by Bach and Busto (2005), which showed that high weekly variation in milking intervals reduced daily milk yield in individual cows. The reduction was highest when weekly variation was >27 %. It was not determined whether the reduced production was due to a lower cell proliferation or a decrease in metabolic rate in secreting cells.

For cows that are unwilling to move more than necessary, the milking intervals can be long in AMS if they are not fetched to the milking unit. In a study by Kohler et al. (2016), the consequence of a single prolonged milking interval of 24 h was investigated. It was shown that all cows were leaking milk during the prolonged milking interval. The prolonged milking interval was also related to an increase in electrical conductivity (Kohler et al., 2016), which was a consequence of damaged blood milk barrier (Bruckmaier, 2004). Kohler et al. (2016)

found that a prolonged milking interval led to edema in the subcutaneous tissue, which was related to the leakage in the blood milk barrier. SCC increased in milk due to the prolonged milking interval, from 66.3 cells/µL in baseline milk, to 216.3 cells/µL in the milk 12 h after the prolonged milking interval.

Milk leakage is related to increased intra mammary pressure (Rovai et al., 2007), which is a result of increased milking intervals (Kohler et al., 2016). Cows that are leaking milk have a wider teat canal, which increases the risk for pathogens to enter the teat (Peeler et al., 2000). Peeler et al. (2000) found that leaking of milk was an important reason for increased mastitis. Infected cows leaking milk contaminate the environment and increase the risk of other cows to become infected. Persson et al. (2003) found that milk leaking were more common in AMS than in conventional milking. However, there was no significant difference found in SCC between cows that were leaking milk and cows that were not. This was explained by the good environmental hygiene in the barn. About one fifth of the leaking in the study occurred less than four hours after milking. Half of those had a failure during milking and were not completely milked on one or more quarters. For cows that were leaking 4-8 hours after milking, one third had a milking failure during the previous milking and for 15 % of the cows that were leaking, 12 hours had passed since the last milking. However, decreased milking intervals do not only have positive effects on udder health. Ouweltjes et al. (2007) found that 3-times milking impaired teat condition, which increased the risk of infection. Both roughness and callosity increased with weeks in lactation. Therefore, it was discussed that, in order to improve udder health, more frequent milking can be used in early lactation to then be reduced after some weeks.

Measuring mastitis

Automatic milking units are fitted with sensors that measure milk quality, for instance SCC and electrical conductivity (Hovinen and Pyörälä, 2011; Jacobs and Siegford, 2012). Milk SCC consists of about 75 % white blood cells (leukocytes) and 25 % milk secreting epithelial cells. The amount of leukocytes in the milk increases in response to bacterial infection (mastitis) and functions as the body's' own defense mechanism. A healthy cow has a SCC level of about 100 000 cells/ml, while an infected udder can have a SCC level of above 1 000 000 cells/ml. The SCC is not only affected by bacterial infection, but also age, parity, breed, season, stress level and stage of lactation. High producing breeds are known to have a higher presence of SCC. However, a SCC level of 200 000 cells/ml on udder quarter and a whole udder SCC level of 400 000 cells/ml is an indication of mastitis (Sharma et al., 2011).

The milk's electrical conductivity (**EC**) is a measure of its concentration of anions and cations. Cows that are suffering from mastitis have an increased level of Na^+ and Cl^- concentration in the milk, which increases the EC (Hovinen and Pyörälä, 2011). Janzekovic et al. (2009) found the EC in a healthy udder to be <5.5 mS/cm. Milner et al. (1996) found that 55 % of the clinical mastitis caused by *S. aureus* and *S. uberis* could be detected on average two milkings before visible signs of mastitis by measuring EC. An increase in EC (defined as an increase of 10 % compared to the rolling average for the four previous milkings) was only seen in connection with infection, which indicates a high sensitivity. A later study by Norberg et al. (2004), concluded 80.6 % of the cases of clinical mastitis, 45.0 % of subclinical mastitis and 74.8 % of health cows could be detected by the EC level. Lucas et al. (2009) found a significant increase in electrical conductivity three days before detection of a mild mastitis.

Not only mastitis increases the EC. It also increases when milk fat content decreases, which can occur in cows with acidosis, fatty liver, ketosis and displaced abomasum. Furthermore, EC increases when milk temperature increases, which increases linearly with ambient temperature. The EC can be used as a disease detection tool, but it is not disease specific and it is therefore just an indicator that something is deviating (Lucas et al., 2009).

Waiting area

Four different types of waiting areas are used in AMS farms: open, closed, and queue waiting areas, and the fourth type is a combination of queue and closed waiting area. Open waiting area means that there is an open space in front of the milking unit, where cows are free to come and go as they want. In some cases it is possible to temporarily close the waiting area to fetch cows to milking. Closed waiting area means that the cows can come into the waiting area by passing a one-way gate or a selection gate. In order to get out the cow must pass the milking unit. Queue area (also called VIP-lane) is a closed waiting area, where the cows are forced by fences to queue in order to enter the milking unit. The first cow to enter the waiting area is the first to enter the milking unit. Queue area + closed waiting area means that selected cows (e.g. low ranked cows that can be standing in a closed waiting area for a long time) are sorted into a VIP-lane and are prioritized to enter the milking unit. The other cows are selected into a closed waiting area.

Cows were in one study found to stand in the waiting area for an average of 1.5 h, ranging from 0.5–3.5 h (Munksgaard et al., 2011). This variation could be explained by the ranking of cows, where cows of higher rank spend less time in the waiting area, while low ranked cows wait until the waiting area is empty (Ketelaar-de Lauwere et al., 1996). Cows that are standing up and especially cows that are standing still for longer periods of time are exposed to a greater risk of getting a hoof defect e.g. sole ulcers and white line disease. Also, wet and dirty claws increase the risk for hoof infections (Blowey, 2005). King et al. (2016) found that the prevalence of lameness was negatively correlated with production, both per cow and day and per milking unit and day. Blowey (2005) pointed out the importance of avoiding overcrowding in waiting areas, to make room for locomotion and thereby avoid lame cows. Cooper et al. (2008) held cows in pens separated from feed and ability to lie down for 2 h and 4 h. They did not see any reduction in milk production. However, the cows showed sign of discomfort, frustration and tiredness in both groups, and the signs were more frequent in the 4 h group. The 2 h group compensated for the lost feeding time when released, but they did not manage to compensate for lost resting time. The 4 h group did not manage to compensate, neither for lost feeding or lost resting when released. The fact that cows in the 2 h group compensated for lost feed but not lost rest indicated that it is more important for them to feed.

Melin et al. (2005) studied cow behavior when using an open waiting area in front of the milking unit, and observed that low ranked cows went back to the cubicles when there were more than three cows waiting in front of the milking unit. By using closed waiting areas instead, the cows can be prevented from leaving and thereby forcing the cows to pass through the milking unit (Uetake et al., 1997). Ketelaar-de Lauwere et al. (2000) found that a closed waiting area tended to slow down the passage rate through the AMS area (i.e. from the selection gate to the exit of the milking unit) in feed first with combined feeding and lying area. This was not seen in milk first were the lying area and feeding area was separated and the cows had to pass the milking unit in order to get feed. Munksgaard et al. (2011) saw a slight trend that cows spend more time in the open waiting area in forced traffic compared with free traffic. Cow in free traffic stand in the waiting area only to access the milking unit while cows in forced traffic also could stand there to access roughage after the milking unit. They speculated that the cows in forced traffic were less motivated to enter the milking unit because they were interested in feed rather than being milked.

Halachmi (2009) performed a simulated test to study the effect of social hierarchy on cow queue length in AMS with open waiting area. There were three experiments, one normal day where the visits were distributed over the whole day, one crowded day where the milking unit had been inactive for a longer period and a crowded day with herd factor. Herd factor meant that management software were set to not allow milking permission for individual cows until 80 % of the herd mates had been milked after the individual cow's last milking. They found that during a normal day the low ranked cows waited on average for 68.9 min, middle ranked cows on average for 10 min and high ranked cows on average for 3.5 minutes. During a crowded day the low ranked cows waited for 472.1 min, middle ranked cows for 101.5 min and high ranked cows for only 5.6 min. When herd factor was used during a crowded day, the waiting time was significantly reduced for low and middle ranked cows (average 412.19 min in the waiting area for low ranked and 93.5 min for middle ranked). It was concluded that herd factor should be recommended. However, there was no proof showing how this affected milk production.

Bedding

In a study by Dohmen et al. (2010), it was found that cleanness of teats and disinfection of the teats after milking was important to reduce new SCC. Both dirty teats and proportion of milkings with failed disinfection were positively correlated to new cows with high SCC. Also, hygiene score of the udder was associated with SCC on cow level. Furthermore, there was a strong correlation between udder hygiene and udder health, and between environmental hygiene and udder hygiene. However, there was no significant correlation between environmental hygiene and udder health. It was discussed that the impact might be too small when environmental hygiene factors were compared separately, but may have a greater impact on udder health all together. Plesch and Knierim (2012) found that frequency of bedding replacement was positively correlated to teat cleanliness. There was also a correlation between bedding height in the rear part of the cubicle and teat cleanliness. Cleanliness of the teats were graded on a scale 1-4 where; 1=clean, 2=slightly dirty, 3=dirty and 4=very dirty. An increase of one centimeter in bedding material was predicted to decrease the proportion of soiled teat tips (grade 3 and 4) by ~2.8 %. Also Magnusson et al. (2008) concluded that the amount of bedding was important for the hygiene of the teats. Plesch and Knierim (2012) found that farms with deep-bedded cubicles had ~8.1 % fewer dirty teats compared to farms with raised cubicles. They argued that it could be a combination of factors that affects teat cleanliness and that farmers that use deep bedding might be more willing to spend more time on cubicle maintenance.

According to Köster et al. (2006), it was important to have comfortable cubicles to avoid that cows were lying in the alleys and thereby get dirty teats. In barns with small amounts of bedding material, cows preferred stalls with rubber mats to those with only concrete. They also rested for longer bouts on a soft rubber surface than they did on concrete and sand. There was no preference of sand bedded stalls compared to concrete stalls. The cows never preferred bare sand compared to other materials (Norring et al., 2010). Furthermore, the amount of bedding material seems important for the cow's choice of stall. Tucker and Weary (2004) investigated cows' preference of lying stall. All stalls were fitted with a geotextile mattress that was covered with 0, 1 or 7.5 kg of sawdust. All cows chose the stall with 7.5 kg of bedding material ≥ 85 % of all the times they were lying down. The number of lying bouts increased with amount of bedding material. However, the lying bouts did not differ in time between the treatments, which according to the authors indicated that the amount of bedding affects the decision to lie down but not the comfort while lying.

Feeding

Cows prefer to eat during daytime and rest and ruminate during the night (Wagner-Storch and Palmer, 2003; Munksgaard et al., 2011). This diurnal pattern and cows' willingness to synchronize their behavior was a disadvantage with respect to the efficiency of the milking unit (Winter & Hillerton, 1995). Though, little evidence has been found that cows want to synchronize their feeding with other cows in the AMS (Munksgaard et al., 2011). Studies have shown that the cows' feeding patterns are more evenly distributed in AMS compared to conventional milking (Wagner-Storch and Palmer, 2003; Munksgaard et al., 2011). However, the overall feeding activity was still reduced during night (Munksgaard et al., 2011).

Hermans et al. (2003) saw a reduction in feeding time and time spent in the roughage area in forced traffic compared to forced traffic with free access to 1/3 of the feeding area. The freely available feeding area was located in the opposite side of the barn compared to the milking unit. It was shown that the cows spent more time in that part of the barn in the traffic situation where they could access the feeding area, compared to the completely forced traffic situation. The number of visits to the milking unit decreased in forced traffic with free access to one part of the feeding area. However, only the non-milking visits were reduced. The number of milking visits was the same in both traffic situations. They argued that free access to one part of the feed bunk was better for the cows' behavior and the capacity of the milking unit since there were more available time for milking. Munksgaard et al. (2011), on the other hand, compared forced traffic with free traffic where the cows had free access to the entire feed bunk. They could not find any difference in eating time and time spent in the roughage area. According to Bach et al. (2009), there was no difference in daily dry matter intake between forced and free traffic. However, they saw that cows in forced traffic ate fewer meals per day, but the average meal was longer. Ketelaar-de Lauwere et al. (2000) saw that cows in milk first spent less time eating than cows in free traffic and feed first. However, they did not consume less feed, but instead they consumed their feed faster. Melin et al. (2007) found that social factors and traffic system affects feeding behavior. Cows in high social rank had both more chews and more time chewing per kg dry matter intake (**DMI**). This was even more distinct in forced traffic, where the access of feed was restricted compared to milk first and free traffic.

Deming et al. (2013) found that cows in free traffic went to be milked on average 67.5 min after feed had been delivered, when delivered two times per day, compared to 199.0 min when feed was delivered only once a day. Belle et al. (2011) compared conventional feeding (**CF**) (i.e. feed is supplied by the farmer) with automatic feeding (**AF**) (i.e. feed is supplied automatically on predefined hours) in AMS farms with free access to the roughage area. The CF and AF farms delivered new feed on average 1.4 and 7.4 times per day respectively. They found no difference in number of milking visits, milking failures or non-milking visits in the milking unit per cow and day between the two systems. However, there was a significant difference in the number of milkings per hour in the morning. AF farms had a greater amount of milkings at 07.00 and 08.00. Oostra et al. (2005) studied the effect of delivering roughage two times per day compared to six times per day in AMS. The cows could move freely between cubicles and roughage area. There was a closed waiting area in front of the milking unit and the cows were fed concentrate in the milking unit. More frequent feeding resulted in more visits to the feed bunk, reduced time in the waiting area (351 s vs. 755 s) and that cows were more evenly distributed in various barn facilities (i.e. waiting area, cubicles and feeding fence). However, the number of milking visits, non-milking visits and failed milking visits did not change when increasing feeding frequency. Vant't Land et al. (2000) found that the number of milkings increases with >20 % when converting to total mixed ration **(TMR)** after feeding unmixed feed for 6 months. The number of visits and refusals increased with >37 %.

DeVires et al. (2003) found that the number of cows increased at the feeding table after feed delivery in a group-housed barn with conventional milking and that the response was much lower after feed push up (i.e. feed is pushed closer to the cows so that they easier can reach it). King et al. (2016) found that more frequent feed push-ups were positively correlated to lying time. Lying time per cow and day increased by 2.5 minutes for each additional feed push-up. DeVires et al. (2005) found that more frequent feeding resulted in more time spent eating in group-housed barns with conventional milking. However, there was no difference in time spent lying, which indicates that less time was spent idle standing. They speculated that more frequent feeding resulted in decreased competition to access the feed bunk and therefore less time spent waiting to access feed. Shabi et al. (2005) found a positive correlation between time spent eating and milk production and suggested that performance can be increased if the cows are allowed to spend more time eating. DeVires et al. (2005) also found that more frequent feeding leads to more evenly distributed feeding over the day. When fed more frequently, cows were less often displaced from the feeding table by other cows. This indicates that more frequent feeding makes it easier for all cows to feed when they want.

Feeding for increased udder health

Provision of fresh feed after milking can increase standing time after milking, which have been shown to be beneficial for udder health. Earlier studies have shown that the teat canal is dilated up to two hours after milking (McDonalds, 1975). However, a more recent study has demonstrated that the teat canal width differs significantly >8 hours after milking compared to the teat canal width before milking (Neijenhuis et al., 2001). Dilated teat canals increased the risk for bacteria to enter the udder. If the cows were lying down immediately after milking, the risk was higher that the udder came in contact with bacteria. Studies have shown that short standing time after milking has been associated with higher risk for intra mammary infection (Deming et al., 2013; Peeler et al., 2000). DeVires et al. (2011) found that the incidence for new intra mammary infection when lying down was lowest 100-135 minutes after milking and that the risk increased again when lying down more than 150 minutes after milking. The only type of infections that was associated with time spent standing after milking were new infections of *coagulase-negative staphylococci* (**CNS**), which are bacteria present in the environment. However, there were no changes in average time spent standing after milking prior a new infection. They argued that standing time might not be the cause, but rather a symptom of a new infection. Watters et al. (2014) saw that the risk for receiving new CNS intra mammary infection was reduced when lying down 90-120 minutes after milking and when feed was delivered one hour prior and 1.5 hours after milking.

Increased feed bunk space, where the cows do not need to compete for feed, and increased frequency of feed push-ups is associated with increased time standing after milking (Watters et al., 2014). In a study by De Vires et al. (2011), cows were housed in a barn with free cow traffic. Feed was delivered once daily and feed push up was done 2-3 times per day. In that study the average time spent standing after milking was 78 minutes. It was shown that the standing time after milking was related to feed manipulation (i.e. whether the feed was delivered or pushed up). The longest standing times after milking occurred when feed were manipulated between one hour before milking and two hours after. This result indicates that feed manipulation can be used to increase standing time after milking. The shortest standing time after milking occurred when manipulation of feed occurred more than four hours after the cows were milked.

Feeding of concentrate

Apart from feeding concentrate to reach desired nutritional value, it is also used to attract the cows to the milking unit in AMS (Halachmi et al., 2000). Various concentrate-feeding strategies have been tested to increase the amount of visits to the milking unit. Feeding a concentrate rich in starch can reduce roughage-neutral detergent fiber digestibility and in turn reduce appetite, DMI and subsequently also milk yield (Miron et al., 2004). Halachmi et al. (2006) found that a pellet rich in digestible Neutral detergent fiber (**NDF**) could replace a concentrate rich in starch without reducing the amount of visits to the milking unit, milk yield or affecting milk content. NDF rich pellets can therefore make it easier to feed a larger amount of concentrate without the risk of getting rumen acidosis. However, the advantage of feeding more concentrate in the milking unit is modest. Bach et al. (2007) concluded that a larger amount of concentrate in the milking unit only increased the amount of visits for those cows that continuously visited the milking unit. The amount of cows that were fetched was still the same when cows were offered more concentrate. Also, milk production and milk composition were the same for both treatments. Cows that received a higher amount of concentrate consumed less of their basal ration. Nevertheless, the total eating time was still the same between the treatments.

Madsen et al. (2010) concluded that the palatability of the concentrate fed in the milking unit was important for the number of visits. In this study, six different concentrates where compared to a standard concentrate. Four concentrates with a carbohydrate base of different grains were studied (Barley, wheat, barley-oats and maize), one rich in fat and one with 100 % artificially dried grass. The cows preferred concentrate with Barley-oats, based on the amount of milking visits (3.31 visits; $P<0.01$) compared to the control (2.96 visits). Also, wheat attracted the cows to the milking unit but not to the same extent (3.13 visits; NS). Fat rich concentrate and artificially dried grass reduced the amount of visits to the milking unit (2.6 visits, $P < 0.05$; and 2.03 visits, $P<0.001$, respectively), while barley and maize had the same effect as the standard concentrate (2.93 visits, NS; and 2.98 visits, NS, respectively).

Management

In a study by King et al. (2016), it was found that the number of cows per milking unit was negatively correlated with milking frequency. Each additional 10 cows per milking unit resulted in a reduction in milking frequency of 0.22 times per cow and day. Conversely, the amount of milk produced per milking unit and day increased by 32.2 kg per each additional cow. This corresponds to the results by Castro et al. (2012), who concluded that the amount of milk produced per milking unit could be maximized by having the maximum number of cows (average 69 cows) per milking unit and between 2.4 and 2.6 milkings per cow and day. However, King et al. (2016) argued that this model was based on these specific herds and that it cannot be used as a general recommendation. The number of cows per milking unit is depending on milking efficiency and management preference. Jacobs & Siegford (2012) reported that each milking unit could serve approximately 60 cows, depending on how many milkings per cow and day the farmers strive for.

King et al. (2016) found that prevalence of lameness was negatively correlated to milk production. However, they also found that more frequent removal of manure from the alleys were associated with a reduction in prevalence of lameness and number of cows that has to be fetched to the milking unit (King et al., 2016). This can also be related to the findings of Munksgaard et al. (2011), who found that a reason for the cows not to visit the milking unit might be that they spend more time in the cubicles because of uncomfortable flooring. Vant't Land et al. (2000) found that the workload for the farmer did not depend on the number of milking units. Total workload was related to time spent fetching cows to the milking unit. However, they found that farmers that had a higher workload often fetched cows to the milking unit the same time every day. The cows were therefore trained to milk at that time of day, which resulted in an ever-increasing amount of work. They concluded that the farmer must observe the cows and make correct interpretation of their behavior to fully take benefit of the capacity of the milking unit.

One of the main advantages with AMS is that automatic sensors measure milk yield, SCC, conductivity, reproductive status, feed intake etc., both on herd level, cow level and teat level. These key indicators make it possible for the farmer to early predict changes in health and to take the right actions. It is also possible to adjust settings in the milking unit, such as milking interval for individual cows. But the amount of data that is recorded in the system can for some be hard to understand and might be misinterpreted or even ignored. A lot of the cow control is automatic and the herd manager is dependent of key indicators to monitor the herd. Traditional management skills need to shift to more technical skills to fully take advantage of the capacity of the AMS (Jacobs and Siegford, 2012). Hansen (2015) performed a study where farmers adaption rate to AMS were investigated by doing interviews with Norwegian farmers. It was found that many farmers thought that it was hard to utilize the AMS as a management tool. There was a lot of information available in management software and some farmers experienced an overload of information. One farmer said that it was important to see each cow behind the figures and not only the herd average. More than half of the farmers mentioned education and participation in various courses in agricultural as important. Three farmers specially pointed out the importance of their technical education as a great advantage. One farmer claimed that there was a relation between how much time that was spent with the cows and how well you succeed with the production. However, the management in AMS has to be done in a different way compared to conventional milking systems. It was concluded that to succeed with AMS the farmers must be proactive and that the management is of more importance than the milking system itself.

Jansen et al. (2009) investigated the effect of farmers' self-reported behavior and attitude on mastitis incidence. Attitude was measured by asking questions of perceptions and opinions and self-reported behavior was analyzed by asking questions about their daily routines. It was conducted that farmers' attitude explained more (17-47 %) of the variance in mastitis incidence than farmers' self-reported behavior (12-14 %). They discussed that the farmers' reference frame of what was normal was an important factor. For example, the farmers would only take actions to decrease a mastitis outbreak if they thought that the mastitis level was a problem. They concluded that mastitis prevention programs should focus more on farmers' motivation and attitude than on their behavior. In a Dutch study that investigated farmers' motivation to improve mastitis management, 74.7 % of the farmers believed in their capability to control the mastitis situation on the farm. The farmers are motivated by economical benefits to improve udder health, but not exclusively. Job satisfaction, over all situation on the farm and healthy animals are equally motivating factors. However, esteem that was directed to the dairy industry as whole was a lower motivation for individual farmers (Valeeva et al., 2007).

In a review article by Hovinen and Pyörälä, (2011), it was determined that udder health was deteriorating when converting from conventional milking to AMS and then remained impaired. However, Svennersten-Sjaunja and Pettersson (2008) contended that management was one of the most important factors and farms with good management can improve udder health when converting to AMS. In a review article by Dufour et al. (2011), it was seen that farms with high bulk tank SCC when installing AMS were at a higher risk of getting increased bulk tank SCC after installation. Moreover, farmers that put more effort into cleaning and maintenance of the milking unit seemed to be more successful in preventing an increase in SCC. Also, the herd manager's attitude towards culling was important to reduce SCC. A proactive culling strategy based on udder conformation, teat lesions and clinical mastitis must be used instead of acting when it is a mastitis outbreak.

Materials and methods

Study population

The study consisted of three parts; a literature study, a questionnaire sent out to dairy farmers with automatic milking systems and six in-depth interviews with selected dairy farmers who were successful in their production. A group of 317 Swedish dairy producers using DeLaval Volontary Milking System (VMS) were invited to participate in the questionnaire. This was roughly 50 % of the Swedish farmers using VMS 2016. A register of VMS farmers, some with predefined traffic system were provided from DeLaval. To ensure that enough of farms of interest, i.e. farms with feed first, milk first and free traffic would be represented, mostly farms with known traffic system were selected for the study. Of the 317 selected farms, 211 farms were previously registered as having feed first, 46 farms as having milk first, 38 farms as having free traffic and in 22 farms the traffic system was unknown.

Recording of data

A questionnaire (see appendix 1) was sent out to 317 Swedish farmers with Voluntary milking system (VMS) from DeLaval. The web-based tool Netigate was used to administrate the questionnaire online. An invitation was sent out both electronically by e-mail and by conventional mail with an instruction on how to find the questionnaire online. Two additional e-mails were sent out as reminders, the first reminder after one week and the second reminder the day before the questionnaire was closed. The questionnaire was open for the farmers to answer for 12 days (15-29 November 2016) and thereafter all answers were compiled. All farmers were offered a dish-brush and ten cinema tickets were raffled to those who completed the questionnaire. Due to few answers from farmers with milk first and free traffic, the questionnaire was opened again for four additional days (8-11 December 2016) and a special reminder were sent out to farms with milk first and free traffic. All farmers that completed the questionnaire this time were offered a cinema ticket. A total of 124 farms (39.1 % of the invited farms) participated in the questionnaire. However, 27 farmers completed too few questions to be used in the study, thus 97 farms (30.6 % of the invited farms) completed the questionnaire.

Data of each farm's milk production (see table 2), udder health and cow traffic were collected from the management software (DelPro, DeLaval). This was managed by connecting to the farmers' computers via the web-based tool LogMeIn. All farmers that participated in the questionnaire were contacted by e-mail or phone to approve connection to DelPro. Of the 97 farms that were contacted, 66 farmers approved connection to DelPro, 10 farmers accepted to send key figures via e-mail and 21 farmers did not approve connection to DelPro, did not use DelPro or did not use LogMeIn. Another three farmers using forced traffic system were removed from the study since the population was too small to analyze, giving that 23.0 % of the invited farms could be used in the study. All data was collected during three days, 11-13 January 2017, except for the data that was sent by e-mail, which were collected during the period 11–18 January 2017. Data of SCC was collected in the questionnaire where the farmers were asked to estimate the farms average SCC during the latest 12 months by selecting one of the following intervals: less than 150 000 cells/ml, 151 000 - 250 000 cells/ml, 251 000 - 350 000 cells/ml or more than 350 000 cells/ml.

Table 2. Variables collected from the farmers management system and what period they include

Variable	Period	Type
Main variables		
Milk per milking unit (kg)	Total production during the period 161101 – 161130	Continuous
Production per cow and day	Average last 7 days	Continuous
Other production related variables		
Number of gate passages	Average last 7 days	Continuous
Number of milkings per cow and day	Average last 7 days	Continuous
Mastitis detection index (MDi)	Average last 3 days	Continuous
Incomplete milkings (%)	Average last 7 days	Continuous
Time per milking	Average for the period 161101 – 161130	Continuous
Milk per milking	Average for the period 161101 – 161130	Continuous
Unoccupied (%) time in milking unit	Average for the period 161101 – 161130	Continuous
Number of milkings per milking unit and day	Average for the period 161101 – 161130	Continuous
Average milk flow during milking	Average for the period 161101 – 161130	Continuous
Conductivity	Average for all teats in the heard at the moment	Continuous
Online cell count (OCC)*	Average last 7 days	Continuous

*Online cell count is complement tool to VMS that measure SCC

Definition of traffic systems

Two questions in the questionnaire were asked to define what traffic system that was used on each individual farm. Different combination of answers in those two questions resulted in different interpretations of traffic system (see table 3). The questions were:

Question 1: Are the lying- and roughage area separated by one-way gates?
1: Yes
2: Yes, but there are a few cubicles in the feeding area as well
3: No

Question 2: Is there a selection gate selecting the cows to the milking unit?
1: No
2: Yes, where the cows are leaving the combined lying- and roughage area
3: Yes, where the cows are leaving the lying area
4: Yes, where the cows are leaving the roughage area

Table 3. Description of how the combinations of answers regarding cow traffic system were interpreted

	Answers options											
Question 1	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**3**	**3**	**3**	**3**
Question 2	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Feed first	X	O	X	O	X	O	O	X	X	O	X	X
Milk first	X	X	O	X	X	X	X	O	X	X	X	X
Free traffic	X	X	X	X	X	X	X	X	O	X	X	X
Forced traffic	O	X	X	X	O	X	X	X	X	X	X	X

O = True, X = False. The table is supposed to be read column wise by picking the answer for question 1 in row 1 and answer for question 2 in row two and then follow the column down to the circle (e.g. if the answer on question one was 2 and answer on question two was 3 the column shows that the traffic system was feed first). The combination of answers in column 11-12 is contradictive and therefor not possible in reality.

Statistical analysis

Results from the questionnaire and the data collected from the farms' management software were analyzed for differences in milk production per milking unit and per cow. Milk production per milking unit was defined as kg milk produced per unit (average kg per milking unit and day for November). Milk production per cow was defined as kg milk produced per cow and day (average for 7 days). Udder health was defined by the variables mastitis detection index (MDi), online cell count (OCC), somatic cell count (SCC) and conductivity.

All independent variables were first analyzed within each of the different traffic systems for simple relationships with Pearson linear correlations, ANOVA, t-test and chi-squared test. Tests with a p-value under 0.05 was defined as significant and p-values <0.1 was defined as having tendency of being significant. All independent variables that at least indicated a difference in milk production (p<0.1) within any traffic system were put into a multiple regression model. The model was analyzed with both MPc and MPu as dependent variable. The independent variables were then removed from the model one by one by removing the variable with highest p-value until all variables had a p-value <0.1. Traffic system was forced into the model and was therefor not removed even if it had highest p-value.

The analysis was performed again to evaluate differences in management independent of traffic system. This time all farms were analyzed together for simple relationships. Those independent variables that had a p-value <0.1 were put into a final multiple regression model and were than removed one by one until only variables with a p-value < 0.1 remained. The model was analyzed with both MPc and MPu as dependent variable. Traffic system was not included in this model.

For questions with more than two possible answers, the answers were grouped together to make greater number of observations (e.g. "most important" and "second most important" was grouped together as "important"). Those variables are indicated in the tables. Variables included in the final multiple regression models for all farms are presented in table 4.

Table 4. Variables included in the multiple regression model

Variable	*Levels*
Part of all cows milked in VMS	90 % or more Less than 90 %
Production system	Conventional Organic
Average SCC for the latest 12 months	≥250 cells/ml* <250 cells/ml*
How often du you check key indicator: Conductivity	Every week* A few times per week Daily*
Do you have slatted floor	Yes No
Which routine is most important to do every day: Check key indicators to find outliers	Less important Important*
Which routine is most important to do every day: Fetch cows to the milking unit	Less important Important*
Which routine is most important to do every day: Clean the milking unit	Less important Important*
Type of feed in feed bunk	Partly mixed ration Only roughage
What du you think of your knowledge in DelPro	Limited* Good*
How often du you check key indicator: Time in waiting area	Every week* A few times per week Daily*
Which feeding factor is most important: Feed should taste good and be attractive	Less important Important*
Milk flow at teat cup removal	60 g/ min 120 g/ min 180 g/ min 240 g/ min 300 g/ min 360 g/ min
Number of milk producing cows per milking unit	Continuous
Percentage of Jersey in the heard	Continuous
Percentage of cross breeds in the heard	Continuous
Number of feed deliveries per day	Continuous
Number of times cleaning the VMS per week	Continuous

* Two variables are grouped together

Interviews

Six farmers were selected to participate in semi structured in-depth interviews; one farm with free traffic, one farm with milk first and four feed first farms. In milk first, the farm with the highest production per milking unit was selected. In free traffic, the farm with the highest production per milking unit and cow was chosen. In feed first, one farm had the highest production per milking unit, one had the highest production per cow and two farms had a balance of both high production per cow and per milking unit. Three farmers were interviewed on their farm, one of each traffic system. In feed first, this was the farm with the highest production per milking unit. The remaining farmers were interviewed by phone. Open interview questions were prepared based on results from the questionnaire and the general aim of the study (see appendix 2). These were used as guidelines during the interview, but if something else interesting came up it was also discussed. The farm visits started with a tour in the barn to see the general layout, feeding system and milking unit area. The interview then was continued sitting down in an office or by a table. The results from the interviews are the farmers' own experiences after working in the systems.

Results

Questionnaire

The study included 66 farms with feed first, 12 farms with milk first and 16 farms with free traffic according to the questions stated to define traffic system in the questionnaire. Only three farms used forced traffic, which was too few to make statistical analysis within that traffic system (see table 6). Those farms were therefor excluded from the study. Our definition of traffic system corresponded to 84 % to the register of farms with predefined traffic systems provided from DeLaval. However, none of the farms defined as forced traffic in our study were previously registered as forced traffic (see table 5).

Table 5. Interpretation of traffic system compared to the predefined register provided from DeLaval

Traffic system	Total	Number corresponding	Percentage corresponding
Feed first	66	58	88
Milk first	12	10	83
Free traffic	16	13	81
Forced traffic	3	0	0

There were little results indicating differences in milk production between the traffic systems. Furthermore, there were no results indicating that specific management factors were more important in one traffic system compared to another. All results presented below are therefor based on the second statistical analyze with all farms, including forced traffic.

Table 6. Number of farms, average number of cows, milking units, groups and cows per milking unit per traffic system

	Feed first	Milk first	Free traffic	Forced traffic
Number of farms	66	12	16	3
Average number of cows milked in AMS	109	126	96	82
Average number of milking units	1.7	1.9	1.5	1.3
Average number of cows per milking unit	61	59	57	58
Average number of groups	1.4	2	1.4	1.7

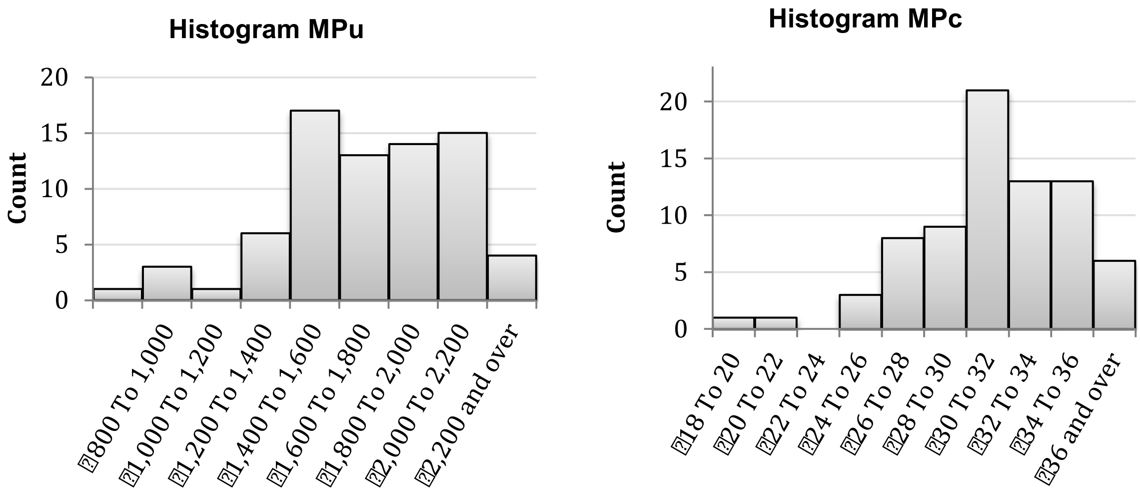

Figure 1. Histogram showing the distribution of data for MPu and MPc

Feeding strategy

The majority of the farms had either partly mixed ration (PMR) or only roughage in the feed bunk, with additional concentrate in automatic feeders and milking unit. The multiple linear regressions showed that farms feeding PMR in feed bunk had on average 113.12 kg higher MPu compared to farms with only roughage in the feed bunk. There was also a tendency for 1.44 kg higher MPc for farms feeding PMR (see table 11).

In the questionnaire, the farmers were asked to grade which two feeding factors they believed were the most important for a high production. The most important factor was graded 2, the second most important factor was graded 1 and other alternatives where left empty and were interpreted as less important. The alternatives were; roughage is delivered often, always have feed in feed bunk, feed should taste good, feed ration is adjusted to all cows' individual energy balance, the concentrate in the milking unit should taste better than other feed or other. Grade 1 (second most important) and grade 2 (most important) were grouped together during analysis as "Important" in all ranking questions. The simple relationship analysis showed that farmers that graded taste of feed as important had 218 kg lower MPu compared to those that graded it as less important (table 10). Number of feed deliveries per day had a tendency to be positively correlated to MPu ($r=0.23$, $p<0.1$), but was not significant (table 8).

Management factors

The farmers where also asked to rank which two routines they believed were the most important to prioritize on a stressful day. The alternatives were; fetch cows that were late to milking, help cows that had spent a long time in waiting area, clean cubicles, control key indicators to find outliers, clean milking unit or other. Grade 1 (second most important) and grade 2 (most important) were grouped together during analysis as "Important" in all ranking questions. The multiple linear regression showed that farmers that had ranked 'fetch cows to the milking unit' as important, had 134.97 kg higher MPu compared to farmers that had ranked it as less important. There were also on average 1.94 kg higher MPc for farms that were prioritizing fetching of cows to the milking unit ($p<0.05$). The multiple regression analysis also showed that 'part of cows milked in VMS' was of importance for milk production. Farmers that had less than 90 % of their cows milked in VMS had 181.49 kg higher MPu compared to those that had 90 % of the cows or more in VMS. There was also a tendency ($p<0.1$) for 2.58 kg higher MPc on farms that had less than 90 % of their cows milked in VMS. Number of cows per milking unit was also of importance for MPu. For every extra cow per milking unit, there was an increase of 28.59 kg MPu. Farms with higher percentage of Jersey cows had lower production. An increase of one percentage point of Jersey cows decreased MPc by 0.08 kg ($p<0.01$). There was also a tendency ($p<0.1$) for decreased MPu by 3.16 kg when the percentage of Jersey increased by one percentage point.

The single relationships showed that milk flow at teat cup removal also was positively correlated to MPu ($r=0.40$; $p<0.01$) and MPc ($r=0.33$; $p<0.01$). Percentage of Jersey breed in the herd was negatively correlated to both MPc and MPu, while crossbreds on the other hand had a tendency to have a weak positive correlation to MPc (table 7 and 8). MPc was also higher when less than 90 % of the cows on the farm were milked in the VMS. Farmers that believed their knowledge in DelPro was good had 212 kg higher MPu compared to farmers that believed their knowledge in DelPro was limited. Organic farms had 163 kg lower MPu compared to conventional farms.

When farmers were asked to rank what was most important to do every day, the results showed on average 304 kg lower MPu for farms that ranked 'cleaning of the milking unit' as important compared to those that ranked it as less important. There was also a tendency ($p<0.1$) for a negative correlation between number of times per week that the milking unit was cleaned and MPu. However, there was a positive correlation between number of times per day that manure was removed from the alleys and MPc ($r=0.27$; $P<0.05$). Farmers who stated that they checked the key indicator "conductivity" every week or less had a higher production per milking unit and day compared to those that checked it a few times per week or daily. There was also a tendency for lower MPc in farms that ranked 'checking key indicators' as important to do every day, compared to those that ranked it as less important.

Barn layout

There was one layout factor related to milk production. The regression model showed that farms with slatted floors had both lower MPu and MPc compared to farms without solid floor (-126.9 kg MPu; $p<0.05$ and -3.05 kg MPc; $p<0.001$). The simple relationships showed that both number of eating and lying places were negatively correlated to MPc ($r=-0.29$; $p<0.05$ and $r=-0.27$; $p<0.05$ respectively).

Udder health

The multiple regression model showed that farmers that answered that they, during the latest 12 months, had a SCC lower than 250 cells/ml had 227.16 kg higher MPu ($p<0.001$) and 3.04 kg higher MPc ($p<0.01$) compared to farms with SCC >250. The simple relationship analysis showed that farms using PMR had higher online cell count (OCC) compared to farms with only roughage in the feed bunk (247 cells/ml and 185 cells/ml respectively). However, farms feeding PMR had lower average milk electrical conductivity compared to farms feeding only roughage (4.32 mS/cm and 4.46 mS/cm respectively). Of the farms with high SCC (average >250 cells/ml), there were significantly more farms that removed manure from the alleys less than 17 times per day compared to those that removed it more often ($p<0.05$).

Both number of cows per milking unit and number of lying places per cow had a tendency to be correlated to OCC ($r=-0.36$; $p<0.1$ and $r=0.33$; $p<0.1$ respectively). Also, farmers that ranked taste of feed as an important feeding factor had a tendency to have higher conductivity compared to farmers that ranked it as less important (average 4.46, p<0.1 and average 4.35, p<0.1 respectively).

Tables

This paragraph compiles all variables related to milk production in the current study. Tables 7-8 shows continuous variables correlated to MPu and MPc. Tables 9-10 complies categorical variables, which significantly or nearly significantly affects MPu and MPc. In table 11 the variables in the final multiple linear regression models are presented.

Table 7. Variables, which was significantly correlated or had a tendency to be correlated to MPc

Correlations with milk per cow and day (MPc)			
Variable	*N*	*p<*	*r*
Milk per milking (kg)	73	0.001	0.74
Average milk flow during milking (kg/min)	72	0.001	0.64
MPu (kg per milking unit and day)	73	0.001	0.62
Kg ECM per cow and year	72	0.001	0.60
Milk flow at teat cup removal (g/min)	59	0.01	0.33
Jersey breed (%)	75	0.01	-0.34
Percentage unoccupied time in milking unit per day	71	0.05	-0.27
Number of times per day manure is removed from the alley	54	0.05	0.27
Number of automatic feeders	75	0.1	0.22
Crossbreds breed (%)	75	0.1	0.21

Table 8. Variables, which was significantly correlated or had a tendency to be correlated to MPu

Correlations with milk per milking unit and day (Mpu)			
Variable	*N*	*p<*	*r*
Milk per milking (kg)	74	0.001	0.85
Number of cows per milking unit	73	0.001	0.80
Milk flow during milking (kg/min)	73	0.001	0.77
Number of milkings per unit and day	73	0.001	0.73
Unoccupied (%)	72	0.001	-0.72
MPc (kg per cow and day)	73	0.001	0.62
Kg ECM per cow and year	71	0.001	0.51
Milk flow at teat cup removal (g/min)	57	0.01	0.40
OCC (cells/ml)	26	0.05	-0.41
Eating places per cow	73	0.05	-0.29
Lying places per cow	71	0.05	-0.27
Jersey breed (%)	74	0.05	-0.23
Number of feed deliveries per day	73	0.1	0.23
Number of milkings per cow and day	74	0.1	-0.22
Number of times per week the milking unit is cleaned on the outside	69	0.1	-0.21

Table 9. ANOVA with variables affecting milk production per cow and day (MPc)

Milk per cow and day (MPc)				
Variable	*Level*	*N*	*Average MPc*	*p<*
Part of all cows milked in VMS	90 % or more	67	30.9	
	Less than 90 %	6	34.9	0.01
SCC	≤250*	58	31.9	0.001
	>250*	16	28.5	
How often is key indicator 'conductivity' checked?	Every week or less*	35	32.2[a]	0.05
	A few times per week	12	29.4[b]	
	Daily*	25	30.5[b]	
Do you have slatted floor?	Yes	20	29.4	0.01
	No	54	31.9	
Which routine is most important to do every day: Check key indicators to find outliers	Less important	55	31.5	0.1
	Important*	18	30.1	
Type of feed in feed bunk	PMR	26	32.2	0.05
	Roughage	48	30.6	

*Two choices of answers are grouped together

[a,b] Numbers within the same column and variable with different superscripts are significantly different from each other

Table 10. ANOVA with variables affecting milk production per milking unit and day (MPu)

Milk production per milking unit and day					
Variable	*Level*	*N*	*Cows per milking unit*	*Average MPu*	*p<*
Type of production	Conventional Organic	49 24	61 59	1 781 1 618	0.05
Part of cows milked in VMS	90 % or more Less than 90 %	65 7	60 63	1 701 1 990	0.05
Knowledge in DelPro	Limited* Good*	14 60	57 61	1 559 1 771	0.05
SCC	≤250* >250*	58 15	60 60	1 785 1 539	0.01
Do you have slatted floor?	Yes No	18 55	58 61	1 586 1 782	0.05
Which routine is most important to do every day: Fetch cows to the milking unit	Less important Important*	16 56	59 60	1 594 1 768	0.05
Which routine is most important to do every day: Clean the milking unit	Less important Important*	64 8	60 58	1 763 1 459	0.05
Type of feed in feed bunk	PMR Roughage	26 47	63 59	1 822 1 678	0.05
Which feeding factor is most important: Feed should taste good and be attractive	Less important Important*	24 50	62 59	1 878 1 660	0.01

*Two choices of answers are grouped together

Table 11. Multiple linear regression model showing the relationship between various factors and MPu and MPc

		MPu			MPc		
Factor	*Level*	*N*	*P<*	*Coefficient*	*N*	*P<*	*Coefficient*
Proportion of cows milked in VMS	90 % or more	62	0.05	0.00	64	0.1	0.00
	Less than 90 %	6		181.49	5		2.58
SCC	≤250	54	0.001	0.00	59	0.01	0.0
	>250	15		-227.16	16		-3.04
Do you have slatted floor?	Yes	17	0.05	0.00	20	0.001	0.0
	No	52		126.9	54		3.05
Type of feed	PMR	24	0.05	0.00	24	0.1	0.00
	Roughage	45		-113.12	46		-1.44
Which routine is most important to do every day: Fetch cows to the milking unit	Less important	15	0.05	0.00	15	0.05	0.00
	Important	53		134.97	54	–	1.94
Number of cows per milking unit	Continuous	69	0.001	28.59	–	–	–
Jersey (%)	Continuous	5	0.1	-3.16	6	0.01	-0.08

Interviews

Six high producing farms were contacted for interviews. Three of the farms, one of each traffic system, were visited and interviewed on the farm and the remaining three farmers were interviewed by phone (see table 12).

Table 12. ID, traffic system and short layout description of the farms selected for interview

Farm ID	Traffic system	Interview type	Short description
MF	Milk first	Farm visit	All cows were held in one group with 74 lying places, one milking unit and a closed waiting area in front of the milking unit.
FT	Free traffic	Farm visit	There were two groups sharing one milking unit. One regular group with 71 places and one special group with 10 places.
FF1	Feed first, type 1	Farm visit	There was one milking unit and a closed waiting area. Cubicles, roughage area and area with concentrate feeders were all separated by gates. There were two groups of milking cows, 87 regular places and 10 places for special cows.
FF2	Feed first, type 2	Phone	There was one milking unit with a closed waiting area. Lying and feeding area was one united section with a separate section with automatic feeders. It was one regular group with 70 lying places and one special group with four lying places. Cows could be sorted into the special group after milking but could not visit the milking unit voluntary from there.
FF3	Feed first, type 2	Phone	There was one milking unit with a closed waiting area. Lying and feeding area was one united section with a separate section with automatic feeders. There was one group of cows with 80 lying places.
FF4	Feed first, type 1	Phone	The barn was divided into two similar sides with two milking units serving each side (four milking units in total). In front of each pair of milking units, there was a closed waiting area with a VIP-lane. Cubicles, feeding area and concentrate feeders were all in separated sections. Each side of the barn had one main group of milking cows (137 lying places for one pair of milking units and 156 lying places for the other pair). There was also a special group with 16 places on each side, which also had access to the milking units.

Feeding

All farms were delivering feed automatically with feed wagon or belt feed and had additional feed in automatic feeders. The MF farmer had installed the automatic feeders a few years after installation of AMS to increase fat and protein content in milk. However, it only resulted in higher milk yield but not higher fat and protein values. But he had observed that cows with short time per milking managed to eat more concentrate when they could access it outside the milking unit as well. The FF1, FF2, FF4 and MF farmers had observed that too much energy in the feed resulted in dull cows and reduced cow traffic. The farmers did not have experience of any larger changes in the feeding system and could therefor not compare their feeding strategy with some other feeding strategies.

The FF1 farm had only roughage in the feed bunk with additional concentrate in automatic feeders and the milking unit. He used to feed PMR, which made the feed tastier, but he had too little cereals for feeding PMR right now. The farmer had found a relationship between feeding frequency and the need of pushing cows in the waiting area. When new feed was delivered every second hour, there were more cows in the waiting area. He experienced that low ranked cows went to be milked the last hour before new feed was delivered. When feed was delivered too often the waiting area was continuously filled with new high ranked cows that pushed the low ranked cows away. Furthermore, the low ranked cows were locked into the waiting area without a chance to exit. When changing feeding frequency to feed delivery every third hour instead, the problem was reduced. He aimed at always having feed in the feed bunk and that there should always be cows feeding. Feed left over was removed once per day.

The FF2 farmer had only silage and straw in the feed bunk and concentrate in automatic feeders. There were different types of concentrate in the milking unit compared to the automatic feeders. Feed was delivered 6 times per day, and there was always feed in the feed bunk. Old feed was removed every morning. He experienced that the cows went to the feed bunk just by the sound of the feeding system. In the night, the feeding system was sometimes running empty just to alert the cows and initiate movement.

The FF3 farmer wanted the cows to eat as much as possible. He fed PMR with grass, peas and oats, which were delivered 12 times per day with a break in the morning to sweep the feed bunk. He believed that the traffic worked well when there were cows feeding at all times. During a breakdown in the feeding system, he had experienced that the cow traffic was reduced when having fewer feed deliveries per day. Therefore, he believed that frequent delivery of feed was the most important factor related to feeding strategy.

The FF4 farmer had PMR in the feed bunk that allowed the cows to produce 25 kg of milk. Additional concentrate was offered in automatic feeders and in the milking unit. PMR was delivered 20 times per day and the feed bunk was swept once a day in the morning. She believed that it was important to mix feed often to have fresh feed.

The MF farmer had experienced that the traffic was working better if the feed bunk was emptied between each feeding. However, it was an organic farm and the cows must therefor always have free access to roughage. He used PMR with grass, peas and straw in the feed bunk, with additional concentrate in the automatic feeders and in the milking unit. He was using the same concentrate in the automatic feeders and in the milking unit. Old feed was removed once daily and feed was delivered every second hour. He had experienced a clear reduction in cow traffic when one feeding event was missed out. After a stop in feeding, all cows wanted to eat at the same time, which also resulted in too many cows in the waiting area.

The FT farmer was delivering feed eight times per day with less feed during midday so she could sweep the feed bunk. There was only roughage in the feed bunk, with additional concentrate in the automatic feeders and the milking unit. She believed that it was important to sweep the feed bunk every day, because she had observed a clear drop in production when not sweeping one day. She thought that it was important to have tasty feed, both in the feed bunk and in the milking unit. Therefore she had chosen to serve the most attractive concentrate in the automatic feeders while less tasty concentrate were served only in the automatic feeders. This feeding strategy was used to increase the number of visits to the milking unit.

Management

Both the FF1 and FF2 farmers thought that good animal material was the most important reason behind their high production. The FF2 and FT farmers mentioned that they spent much time with the cows, which they believed was important in order to get a high production. The FF2 farmer also told that they were very accurate and had clear routines. Also FF3 mentioned time spent in the barn as important and that it was important to just pass by the barn to see that everything was all right a few times per day. The FF1 farmer, on the other hand, was not interested in spending too much time in the barn. He was having a part time job as carpenter and spent about 50 % of his time not working with the cows. The FF3 farmer thought that it was important to be proactive and dare to try new things. Also, he believed that it was important to have engagement in the work. Also the FF4 farmer mentioned good routines as important and they had managed to find good employees that worked well together. She described herself as optimistic and full of enthusiasm, which she believed was important. The MF farmer was accurate with fertility and inseminations and aimed for a good animal flow (i.e. to have steady average number of 'days in milk'). Both the FT and FF1 farmers were highlighting the importance of healthy animals and good barn hygiene.

FF1 had only milk producing cows in AMS. Dry cows could occur but that was only when there was a lack of space in the tie stall barn. The FF2, FF3, FF4 and FT farmers allowed heifers to be introduced to the VMS in the group before calving. MF kept some cows and heifers in the AMS group before they were sent to slaughter.

All farmers had automatic setting of milking permission in batches, depending on milk yield and stage of lactation. All of the farmers avoided manual settings, if no problem with udder health was noted. FF1 wanted to control the number of milkings per cow and used time per milking and performance (value describing time used to attach the teat cups) to control capacity of the VMS. However, he was not interested in working a lot in DelPro or learning more. FT was using performance and milk flow per cow to control the capacity of the VMS. If there were low numbers she checked the individual cow and re-learned the robotic arm if necessary. She was taking all courses that were available and wanted to learn as much as possible and take part of new science. The MF farmer thought that animal flow in AMS was most important and was carefully checking the average number of days in milk for the herd. He was also checking performance and had experienced that a low number was often dependent on hairy udders. The FF2 farmer aimed at having high milk per milking and was not interested in having cows that came to the milking unit to deliver 8-9 liters. He did use DelPro, but was not active in doing own lists anymore. The FF3 farmer thought that many cows in the system were good for the cow traffic. He was trying to have about 70 milking cows and then fill up with heifers that were introduced to the milking unit to a total of about 80 animals in the system. He claimed that feeding activity was important for cow traffic and that the movement of the feeding wagon was making cows move. He was interested in statistics and made his own history files of the cows and recorded milk yield of all deliveries to the dairy. He had taken consultation in how to optimize DelPro and was also trying new technology. The FF4 farmer was striving for even cow traffic with as little disturbance as possible (e.g. she was avoiding changes around the milking unit like newly washed gates, which could scare the cows to not enter the milking unit). She was having a good knowledge in DelPro and was interested in graphs, statistics and key indicators. She experience that it was hard to find good workers who had the right knowledge in how to take care of an AMS. She stated that there is a need for more technical skills compared to conventional milking systems and it takes more time to teach this system to new workers.

The farmers had different thoughts about fetching cows to the milking unit or not. The FF1 farmer avoided to fetch cows to the milking unit and was only fetching cows if they refused to go to milking. He was not worried about cows passing 15 hours since last milking and he had cows that always were red (i.e. time since last milking was too long according to the farmers setting of milking permission) when they were milked. However, he pushed more cows from the waiting area to the milking unit than from the cubicle or feeding area to the waiting area. The FF4 farmer was not fetching cows at all. If the cows did not milk voluntary 2 times per day, they were moved to the tie stall barn. She expected the cows to manage themselves and did not push cows in the waiting area to enter the milking unit. The farmer in FT was avoiding fetching cows to the milking unit. If there were dull cows that did not milk voluntarily, they were moved to the special group where they pushed the cows 2-3 times per day if not milking voluntarily. When cows in the special group were milking voluntary at least 3 times per day, she was moving them back to the regular group. The FF2 farmer had 4-5 cows per day that did not go to milking voluntary and that were therefore fetched to the milking unit. He did not see any problem with fetching cows, but was rather fetching cows continuously when in the barn, if it was needed. It was mostly cows were expected to not go to milking voluntarily, so called “assistant cows”, that were probably either dull or lame. The FF3 farmer was fetching a few cows that needed to be milked. The MF farmer was fetching cows if it was needed and he experienced that it was always the same cows.

There was only one farmer who did not have much contact with other farmers. He experienced that his neighbor farmers were more of competitors than colleagues. Many of the neighbor farmers were expanding and there was competition for land. He felt like he was chained to the farm because of the alarm from the VMS. Previously, he had had contact with other farmers through the dairy association, but since the meetings where moved to a village further away he had not managed to participate. However, he was taking help from consultants and veterinarians and preferred to let others do things that he was not good at. The FF2 farmer was having good contact with neighbor farmers and was part of an experience group with organic farmers, which he had taken a lot of experiences from. FF3 was active in many associations and liked to share experiences with others. He described himself as innovative, liked to try new things and to go his own way. The FF4 farmer had a lot of visits from foreign farmers since their barn is an exhibition barn for DeLaval. She thought that it was good to take advantage of others knowledge and experiences. All personnel on her farm liked to compete and set goals to improve their farm. Thereby, they were pushing each other to become better. The MF farmer was part of an experience group that had meetings 4-5 times per year. He had a close friend who was a previous service technician who helped him with technical problems and he also had good contact with neighbor farmers. He thought that it is important to have a good network to share experiences with. The FT farmer had much contact with other farmers and was part of an experience group. He liked to share experiences with other farmers and try to take part of new science and education.

Barn layout

FF1, FF4 and FT had a special group for cows that needed extra care. Cows in these groups could visit the milking unit voluntarily and then be directed back to their group. The FF1 farmer used this group for cows with contagious mastitis. The FT farmer had this group for cows that were dull, newly calved, lame or sick and needed to be pushed to the milking unit or needed extra supervision. The cows were pushed 2-3 times per day if not milking voluntary. When they were milking voluntarily at least three times per day, they were transferred back to the regular group. The FF4 farmer had a special group for cows/heifers that should calve or were newly calved, cows that needed extra supervision or were weaker. This group had shorter distance to the milking unit and it was easier to look over and observe these cows. The FF2 farmer had the possibility to select cows to a special group after milking, but had to let the cows out manually to be milked. Both the FF3 and MF farmers had only one group of cows.

The FF1, FF2, FF3 and MF farmers all had a closed waiting area and experienced a need of pushing cows from the waiting area into the milking unit. Some individual cows could be standing there for up to 2-3 hours. The FF2 farmer had once tried to change the closed waiting area to a queue waiting area. However, it only lasted for one day since the cows were fighting too much. FF3 moved cows from the AMS to a free stall barn with milking parlor if they were standing too long in the waiting area. He experienced that irregular milking intervals, which could happen if the cows were standing long times in the waiting area, resulted in deteriorated udder health. The MF farmer did not mind pushing cows to the milking unit, when standing too long in the waiting area. The FF4 farmer had a closed waiting area with a VIP-lane for low ranked and sick cows. Cows with long time in waiting area were moved to the VIP-lane and it often appeared that these cows were sick or something was wrong. When the cows had become stronger, the farmer tried to move them back from the VIP-lane to the regular waiting area. Thus, there were never any high ranked cows in VIP-lane.

Four of the six interviewed farmers had an alternative milking system where they also milked cows. The FF1 farmer had an old tie stall barn for low producing cows and cows that did not fit into the AMS. The FF3 and MF farmers milked mastitis cows and newly calved cows and heifers in another system than the AMS, until they released their milk properly and had stopped kicking. Both the FF3 and FF4 farmers had only problem free cows in the AMS. The FF4 farmer was having a rule that the cows must be milked voluntarily at least two times per day in order to be in the AMS, otherwise they were moved to the tie stall. Neither the FF2 nor FT farmers had another system than the AMS to milk their cows and none of them omitted it either.

Discussion

The results showed no difference in milk production between the different traffic systems. Previous studies have compared free traffic, forced traffic and milk first and found no clear differences (Bach et al., 2009; Hermans et al., 2003; Munksgaard et al., 2011). There were no previous studies found comparing feed first with other traffic systems. Thus, our hypothesis that traffic system affects milk production in AMS could not be supported by these results. The management factors from the questionnaire were also tested within each traffic system without finding any clear results. This indicates that none of the management factors tested had a greater importance in any specific traffic system. However, there were only nine milk first and nine free traffic farms participating with all required data. The rather small sample sizes resulted in a number of analysis that were not possible to run due to too limited amount of data.

Most of the interviewed farmers showed a great interest in the production and were seeking information to improve their production. Several farmers seemed interested and engaged in their work and were participating in available courses. They had a great network of neighbor farmers, experience groups and consults that could support them in their work and exchange experiences. It was likely to believe that it was the farmers' management that was affecting milk production, rather than the choice of traffic system. However, the FF1 farmer was deviating from the other farmers interviewed. He thought that his knowledge in DelPro was enough and he was not interested in learning more. He also had little contact with other farmers and because of his other part time job he did not spend more time than necessary in the barn. However, he only had high and middle yielding cows in AMS, which could be one explanation for the high production.

Also, there was no evidence in the results that traffic system or specific management factors within traffic system had a major impact on milk production, wherefore the analysis was further focused on finding important factors independent of traffic system. The following discussion is thus based on the result found when analyzing all farms together. The data of MPu and MPc were not normally distributed in this study, but since other studies have found normal distribution in milk yield we found reason to believe that our results were trustful (Bach et al., 2007; Archer et al., 2010).

Feed management

The multiple linear regressions showed that farmers that fed PMR in the feed bunk, with additional concentrate in automatic feeders and milking unit, had 113 kg higher MPu compared to farms with only roughage in the feed bunk. DeVires and Gill (2012) found that more palatable feed increased DMI and thereby milk production. The higher production can be explained by higher feed intake. The regression model also showed a tendency for 1.44 kg higher MPc for farms feeding PMR compared to roughage. An increase in MPu due to increased feed intake is also expected to increase MPc. However, there was also a significant difference in percentage unoccupied time in the milking unit between farms feeding PMR and farms feeding only roughage in the feed bunk. Farms feeding PMR had on average 16.3 % unoccupied time in the milking unit and farms feeding only roughage had on average 20.8 % unoccupied time ($p<0.05$). There was also a tendency for more milkings per milking unit for farms feeding PMR compared to farm feeding only roughage (average 151 milkings per milking unit for PMR and 145 for roughage, $p=0.08$). This may indicate that farms feeding PMR better utilize the capacity of the milking unit, but it needs to be confirmed with more extensive studies. PMR is more palatable and it is likely to believe that farms feeding PMR have more visits to the feed bunk, higher feed intake, more active cows and thereby more visits to the milking unit. During the interviews, it was found that some of the high producing farms fed PMR, but not all. The FF1 farmer experienced that PMR made the feed tastier, which he thought was beneficial for the production. The FF4 farmer believed that it was important to mix new PMR often to always have fresh feed. On the other hand, the FF1, FF2, FF4 and MF farmers had experienced that too much energy in the feed made the cows dull, which was negative for cow traffic. The FF4 farmer was therefor careful not to make mixes too high in energy.

The simple relationships presented in this study can give an indication of what factors that are affecting milk production. However, the results from the multiple regression model, presented in table 11 are more reliable since the results have counted for the impact of multiple variables (e.g. number of cows per milking unit, which have a great impact on MPu). The simple relationships showed that farmers that ranked taste of feed as an important feeding factor had 218 kg lower MPu compared to those that ranked taste as less important. However, these analyses were not compensating for the number of cows per milking unit. Farms that ranked taste as less important had on average three more cows per milking unit compared to those that ranked it as important. However, three cows cannot alone explain the whole difference in MPu. DeVires and Gill (2012) found that more palatable feed increased milk production per cow. A decrease in milk production when prioritizing taste of feed is therefor unexpected. One explanation for our results might be that those farmers who were putting a lot of effort into taste of feed also spent less time on something that was even more important. It was shown that 70 % of the farmers that ranked taste of feed as important did not feed with PMR. It is not clear what actions those farmers took to make the feed tastier or if they just believed it was important but did not put that much effort into it.

Number of feed deliveries per day had a tendency ($p<0.1$) to be correlated to MPu in the simple relationships, but it was not significant. Belle et al. (2011) found no difference in number of milking visits when comparing farms with automatic feeding (average 7.4 times per day) and manual feeding (average 1.4 times per day). However, they did not publish any results showing how feeding frequency affected milk production. In the interviews, one farmer had experienced that feeding frequency affected cow traffic. He was normally feeding 12 times per day, but during a breakdown in the feeding system he was delivering feed manually with a tractor pulled feed wagon, which resulted in less feed deliveries per day. He was then experiencing a great drop in the cows' movement, which led him to conclude feeding frequency to be the most important feeding factor affecting milk production. The FF2 farmer experienced that only the sound of the feeding system was enough to make the cows move in the barn and was therefor running it empty a few times per day. The FF1 farmer, on the other hand, experienced that too frequent feeding resulted in uneven activity. When new feed was delivered the cows passed the selection gate and the waiting area continuously being filled up with cows of higher rank, which prevented low ranked cows to access the milking unit. However, this is probably a greater problem in guided traffic systems (i.e. feed first and milk first), where the cows always must pass the selection gate to get to or from the roughage area. There was great variation in MPu between farms with the same feeding frequency (see figure 2). Feeding frequency might have an impact on the cows' movement on individual farms, but its impact on milk production on both cow level and per milking unit is probably moderate, if any.

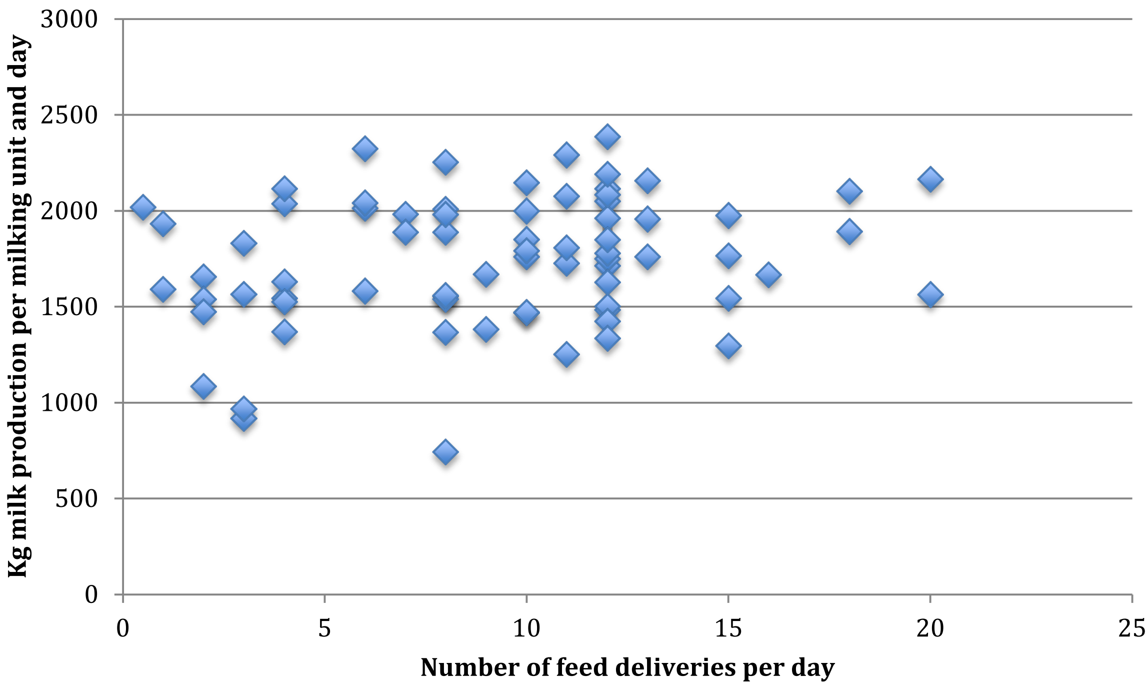

Figure 2. Number of feed deliveries per day and milk production per milking unit

Management factors

The multiple regression models showed that farms that had 10 % or more of their cows milked in another system than VMS had 181 kg higher MPu compared to those that had 90 % or more of their cows in VMS. There was also a tendency ($p<0.1$) for higher MPc for these farms. Four of the six farmers interviewed in the study had a proportion of their cows milked in another system. They used the conventional milking system for problem, newly calved, sick and low producing cows. The strategies for selection of which cows that were milked in the different systems varied between the farms, but the conventional milking system was in general used as a complement to make the work in the AMS easier. Having another system for "problem cows" is beneficial for the efficiency of the VMS and can reduce the time per milking (e.g. cows with a low milk flow rate, cows with an udder shape that makes it hard for the milking unit to locate the teats and cows that hesitate more before entering and exiting the milking unit all takes time from the total time budget in the milking unit). Moving these cows to another milking system makes room for efficient "problem free" cows and thereby a higher MPu. However, many farmers invest in AMS to be more flexible and released from the two times per day milking (Hansen et al. 2015) and using of two types of milking systems might not be suitable for all farmers. The FT and FF2 farmers had all their cows milked in AMS and felt no need for an alternative milking system. For further investigations, it would be interesting to also account for profit, cost effectiveness and milk production on the total farm.

It was also shown in the multiple linear regressions that farmers who ranked 'fetch cows to the milking unit' as an important routine to do every day had 135 kg higher MPu and 1.94 kg higher MPc compared to farmers that ranked it as less important. However, there was no correlation between the number of cows that were fetched to the milking unit per day and MPu or MPc. On the other hand, those farmers that had ranked 'fetch cows' as important also fetched significantly more cows compared to those that ranked it as less important (8.1 vs. 1.6 cows per day respectively; $p<0.001$). Vant't Land et al. (2000) found that farmers who were fetching cows to the milking unit constantly elevated the need of fetching cows. However, in this current study there was no pattern shown of what strategy that was most commonly used among the farmers interviewed. The FF1 farmer avoided fetching cows as much as possible and was not worried if the time since last milking had passed 15 hours. The FF2 and FF3 farmers were keeping an eye on the milking intervals when working in the barn and pushed cows if needed. The FF4 farmer had only "problem free" cows in the AMS and cows that were not milking voluntarily were moved to a conventional milking system. The FT and FF3 farmers, who did not fetch cows in the ordinary group, however fetched cows in the special group if they were not milking voluntarily. These results indicate that the number of cows fetched to the milking unit is of little importance, but it seems important to fetch cows that are in need of assistance. However, on farms where there are only "problem free" cows in AMS, the need to prioritize fetching is lower.

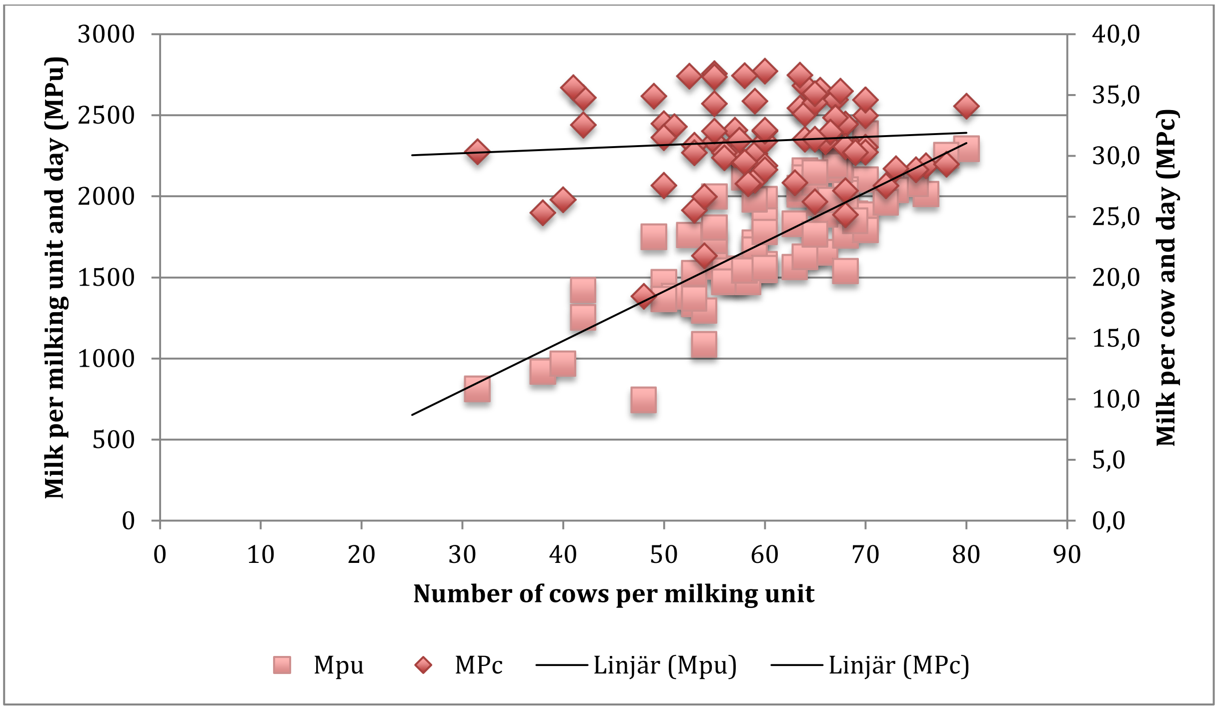

Figure 3. Number of cows per milking unit and its relation to both MPu and MPc

Number of cows per milking unit was significantly correlated to MPu, but it had no significant correlation to MPc. Earlier studies have shown that number of cows per milking unit is negatively correlated to number of milkings per cow and day (King et al., 2016). However, our results showed a slightly positive trend line for the correlation between MPc and number of cows per milking unit (see figure 3). It is previously known that an increase in number of milkings per cow and day will increase MPc (Klei et al., 1997; Melin et al., 2005; Wright et al., 2013). Therefore, an increase in number of cows per milking unit is expected to decrease milk production per cow and day. A model to calculate the optimal number of cows per milking unit on individual farms would be a useful tool to utilize efficiency and profit of the milking unit. Castro et al. (2012) have earlier built a model to calculate the optimum number of cows per milking unit on Spanish farms. However, King et al. (2016) argued that this model only was valid for those specific farms and not useful as a general model. This could therefore be a relevant issue for further studies.

Percentage of Jersey cows in the heard had a tendency ($p<0.1$) to decrease MPu and was significantly correlated ($p<0.01$) to MPc. Statistic of milk production in Sweden for 2016 shows that average milk production per cow and year were 8906 kg ECM for Jersey cows, compared to 9747 kg and 10452 kg for Swedish red and Holstein respectively (Växa Sverige, 2017). Our results are therefor expected.

The simple relationships showed that there was 163 kg lower MPu in organic farms compared to conventional farms. It is previously known that organic farms tend to have lower production because they use less concentrate in feed and/or because of lower energy levels in roughage (Schwendel et al., 2015). However, the difference in our results was not strongly significant and there was no difference shown in the multiple regression models. This indicates that organic farms can reach the same production levels as conventional farms.

The farmers were asked to grade their knowledge in DelPro and it was shown that farmers that rated their knowledge as "good" had a significantly higher MPu compared to farmers that rated it as "limited". However, the difference of 212 kg most likely depended on the number of cows per milking unit rather than knowledge since farmers that rated their knowledge as good had on average four more cows per milking unit.

Farmers that rated 'cleaning the milking unit' as one of the two most important routines to do every day had on average 304 kg lower MPu compared to those that rated it as less important. It differed on average two cows per milking unit between the groups, which can explain some of the difference. But the difference in MPu corresponds to the milk production of about 9.5 cows. When studying the data, it turned out there were only eight farms that prioritized cleaning of the milking unit. One of them had only 48 cows per milking unit and thereby a milk production per milking unit of only 743 kg, which probably greatly affected the average value. However, there was a tendency ($p<0.1$) for a negative correlation between MPu and number of times per week the milking unit was cleaned externally. The FF3 farmer experienced that too big changes, i.e. newly washed gates, could scare the cows and prevent them from entering the milking unit. It is possible that too frequent washing of the milking unit disturbs the animal flow in the system and thereby are having a reducing effect on MPu. However, this study provides too little evidence to draw any conclusions. The impact of frequent cleaning of the milking unit on milk production could be further investigated in later studies.

Farms that checked key indicator 'conductivity' every week or less had higher MPc compared to farms that checked it more often. But, when comparing average conductivity between those that answered 'every week or less', 'a few times per week' or 'daily' it was found that there was no difference. This indicates that milk conductivity is not affected by the number of times it is checked and that the difference in MPc is dependent on chance.

Barn layout

The multiple regression models showed that farms with slatted floor had both lower MPu and MPc (average 126.9 kg MPu and 3.05 kg MPc respectively) compared to farms with solid floor. Telezhenko and Bergsten (2005) found that cows on slatted concrete floor had the lowest walking speed compared to solid concrete floor and solid and slatted floors covered with rubber mats. This was explained by the lower friction on slatted concrete compared to other floor types. This indicates that the reduced milk production were dependent on reduced locomotion on farms with slatted floor. When studying the data, it was shown that farms with slatted floor had significantly higher percentage of unoccupied time in the milking unit compared to farms with solid floor (22.4 % for slatted floor and 17.9 % for solid floor, $p<0.05$). Also, this result indicates that the lower milk production on slatted floor depended on reduced locomotion. Barkema et al. (2009) found that cows on completely slatted floor had lower mastitis incident caused by *Escherichia coli* compared to farms with not completely slatted floor. This was explained by the lower exposure to environmental pathogens. However, Köster et al. (2005) did not find any correlation between alley hygiene and SCC, although there was a correlation between cubicle hygiene and SCC. Dirty alleys also increase the risk to bring dirt into the cubicles. Since high SCC is related to reduced milk production (Seegers, 2003), it is likely to believe that farms with slatted floor have lower barn hygiene. However, our results showed no difference in SCC, OCC or conductivity between farms with slatted or solid floors. It was found that farms with high SCC removed manure from the alleys less often, ≤16 times per day. Farms with low average SCC (≤250 cells/ml) were more likely to remove manure 17 times or more. Farms with slatted floor were not included in the analysis, but it indicates that more frequent removal of manure from the alleys is favorable for udder health. Some of the farms with slatted floor also had scrapers that removed manure continuously. However, that parameter was not included in any statistical analyses. This might explain why there was no difference in udder health between slatted and solid floors. Thus, the results indicate that slatted floor have a negative impact on milk production in AMS, although a more extended study is needed to investigate its impact in detail.

Both lying and eating places were negatively correlated to MPu ($r=-0.23$ for lying places and $r=-0.27$ for eating places; $p<0.05$). One eating place was calculated as one place in the feeding fence or 0.7 m of the feed bunk when using neck rail. The number of cows per milking unit was negatively correlated to both lying and eating places and positively correlated to MPu. When the number of cows per milking unit increases, there will be an increase in MPu and a decrease in number of lying and eating places per cow. These results can therefor most likely be explained by the consecutive increase in number of cows per milking unit.

Udder health

The multiple linear regression show that farms with a SCC over 250 cells/ml have both lower MPu (average 227 kg loss, $p<0.001$) and lower MPc (average 3 kg loss, $p<0.01$). These results are in line with previous studies (Seegers et al. 2003). Farms that were using PMR had significantly higher OCC compared to farms that only served roughage in the feed bunk (247 cells/ml and 185 cells/ml respectively). PMR contains more easily accessible energy, which, in combination with additional oxygen due to feed mixing, increases the risk for growth of microorganisms in feed. Unwanted microorganisms in the feed can result in udder infections and an increase in OCC (Seppälä et al., 2010). However, our results indicate that feeding with PMR increases feed intake, but spoiled PMR is expected to decrease feed intake (Seppälä et al., 2010). The higher OCC level for farms feeding with PMR are most likely depending on chance. The majority of the farms were not measuring OCC since it is not included in the base package when buying VMS. It was only 26 of 76 farmers that were using OCC, which makes the results less trustful. Electrical conductivity in milk is another tool to measure udder health in dairy cows. It was shown that farms with PMR had a milk conductivity of average 4.32 mS/cm and farms with roughage 4.46 mS/cm. These numbers indicates that the cows are healthier when feeding with PMR. However, conductivity is not a disease specific tool and the numbers are based on an average from the very last milking. It is not possible to draw any conclusions from our results on how feeding with PMR affects udder health.

Conclusions

The results in this study found that MPu and MPc were not affected by cow traffic system, but were rather affected by the farmer's management. Farms feeding PMR had higher MPu and a tendency for higher MPc, which was explained by higher feed intake and the lower percentage of unoccupied time in milking unit, indicating more locomotion when feeding PMR. Number of cows fetched to the milking unit had no effect on milk production. However, it seems important to fetch selected cows that do not milk voluntary. Farms with high bulk milk SCC had both lower MPu and MPc compared to farms with lower SCC. Farms with slatted floor had lower MPu, MPc and higher percentage of unoccupied time in the milking unit compared to farms with solid floors. These results might indicate that the cows experience slatted floors as less comfortable and thereby reduce their walking speed and locomotion.

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Appendix 1 Questionnaire

Overview

What is your ID-number?
Your ID number is found in the email or mail in which you were invited to the survey

Textbox

All questions in the survey are based in management routines regarding the animals housed in AMS groups, no other pars of the barn.

Are you in charge of the milking cows?

- Yes
- No

How many years experience of milk production do you have?

Textbox

What type of production is it?

- Convectional
- Organic

How many animals is it in total in the AMS group/groups?

Textbox

How many of these are producing milk right now?

Textbox

Which breeds do you have among the milking cows and how many cows is it of each breed?
Crossbreeds are stated as "crossbreed".
E.g. Holstein 25 pcs, SRB 38 pcs, crossbreeds 20 pcs etc.

Textbox

How much milk do the cows produce on average each year?
State as kg ECM/cow, rolling 12 months

Textbox

The proportion of cows milked in AMS?

- 90 % or more
- Less then 90 %

How often are you seeking information from any of the following if you are having a problem in the heard?				
	Never	Moderately rare	Moderately often	Always
Experience groups				
News papers from consultations				
Personal consultation (consultation agency or veterinarian)				
Searching on internet				
Internet forums or groups on social media				
Contact with other farmers				
Books/papers				

Which of following do you think is most important to reach a profitable production?
Rank the 2 most important, where 1 is most important and 2 second most important.

- Health (Udder health, leg/hoof health etc.)
- Milking (Milk quality, return, efficiency etc.)
- Work load (Easy working environment, self-propelled system)
- Feed (Quality, feed ration, feeding strategy)
- Breeding (Fertility, breeding material, exclusion of cows)
- Other

Is there another factor you think is equivalent important?

Textbox

Management

What du you think of your knowledge in DelPro?

- Very limited
- Moderately limited
- Moderately good
- Very good

Would you work more in DelPro if you had more knowledge of it?

- Yes
- No

Have you bought consultation in how to take advantage of DelPro? (More than what you received when VMS was installed)

- Yes
- No

How is the milking permission controlled?

- Automatic
- Automatic with exception for individual cows
- Adjusted manually for each cow

Do you use feed tables in DelPro to control concentrate ration in automatic feeders and/or in the milking unit?

- Yes all cows are fed according to the tables
- Yes, some cows/groups are fed according to feed tables
- No, all concentrate feed is controlled manually
- No, the feeding consulter is transferring data directly to DelPro

What bulk tank cell score would you esteem that you have had on average the latest 12 months?

- Less than 150 000
- 151 000 – 250 000
- 251 000 – 350 000
- More than 350 000

How great part (%) of the cows is incomplete milked on average each day?
You can find the percentage incomplete cow on the first page in DelPro (monitor board) or under the page system statistics.

Textbox

At which milk flow rate is the teat cups removed?
State as grams/minute

Textbox

Which vacuum level are you using during milking?
State as kPa

Textbox

Is there any function in DelPro that you are missing?

Textbox

How often do you check following key indicators?						
	Less than every week	Every week	A few times per week	Every day	A few times per day	Missing the function
Concentrate intake						
Time since last milking						
Incomplete cows						
Milk yield						
Number of milkings per cow and day						
Number of milkings per milking unit						
Number of gate passages						
Number of visits in milking unit						
Time in waiting area						
Cow Monitor (page in DelPro)						
Conductivity						
OCC (Online cell counter)						
MDi (Mastitis detection index)						

Animal places

In following questions we want you to state what is true for the total number of cows in the AMS groups

What is the main type of feed front used?

- Neck rail
- Feed fence
- Feed stalls

If you have neck rail, state number of meter:

Textbox

If you have feed fence or feed stalls, state number of places:

Textbox

How many drinking places is it?
Water bowls should be states as number of pieces, and water troughs is stated as number of meters

Number of water bowls is:

Textbox

Number of meter water troughs is:

Textbox

Number of lying places is:

Textbox

What bedding material is used in the cubicles?

- Only concrete
- Math without soft foundation
- Mattress
- Water bed
- Deep straw, more than 10 cm
- Other: (Textbox)

How much litter is used in the cubicles?

- More than 3 cm
- 3 cm or less

Total number of milking units is:

Textbox

Number of groups with milking cows is:
With group we mean cows that are separated in different sections

Textbox

If it is 2 groups or more: Are the grouping of cows based on any criteria?
1-2 choices is possible

- No, the groups are not separated on any specific criteria
- Milk yield
- Number of lactations
- Number of days since calving
- Udder health
- Pregnancy status
- Newly calved
- Other: (textbox)

Do you have different traffic systems for different groups?

- Yes
- No
- It is only one group

Barn layout and traffic system

In the following questions we want you to answer what is true for the group you think is best functioning

How many animals is it in the group?

Textbox

State the name of the milking unit/units in the group:

Textbox

Are the lying area and the roughage area separated from each other with one-way gates?

- Yes
- Yes, but there are cubicles in the roughage area as well
- No

Is there a selection gate that is selecting cows to milking?

- No
- Yes, where the cows are leaving the combined lying- and roughage area
- Yes, where the cows are leaving the lying area
- Yes, where the cows are leaving the roughage area

Do you have concentrate feeders?

- Yes, in the combined lying- and roughage area
- Yes, in the lying area
- Yes in the roughage area
- Yes, in a separated pen
- No

How many concentrate feeders is there in the group?
The milking unit is not counted as a concentrate feeder

Textbox

What type of waiting area is there in front of the milking unit/units?

- No waiting area (possibility to close temporary can occur)
- Closed waiting area (the cows must pass the milking unit to exit)
- Closed waiting area + VIP-lane (selected cow are waiting in a row and are prioritized to enter the milking unit)
- VIP- lane (all cows are waiting in a row)
- Other, explain: (Textbox)

How are the cows exiting to the pasture?

- Selection gate after the milking unit
- Selection gate from lying area
- Selection gate from the roughage area
- One-way gate from lying area
- One-way gate from the roughage area
- One-way gate after the milking unit
- It is open for the cows to come and go as they want
- Other: (textbox)

How are the cows entering the barn from pasture?

- Selection gate
- One-way gate to the roughage area
- One-way gate to the lying area
- It is open for the cows to come and go as they want
- Other: (textbox)

Routines

Do you have defined routines for the cow management?

- Yes
- No

How many cows are you fetching to the milking unit per day?
If you are fetching the same cow more than once, count all fetches

Textbox

How many times per day is the cubicles cleaned?

Textbox

How many times per day is the manure removed from the paths?
If you have slatted floor stat "slatted floor"

Textbox

How many times per week is the milking unit cleaned on the outside?

Textbox

Is it routine to:				
	Never	**Moderately rare**	**Moderately often**	**Always**
Control that incomplete cows are completely milked?				
Introduce cows to the milking unit before they are calving?				
Help cow to come to the milking unit first days after calving?				
Re-learn the robotic arm if it has a problem finding one or more teat?				

Which of following routines do you think is the most important to prioritize every day?
Rank the 2 most important where 1 is the most important and 2 is the second most important

- Fetch cow to the milking unit (incomplete cows, cows with long milking intervals, cows with high SCC etc.)
- Help cows that have been standing in the waiting area for a long time to get into the milking unit
- Clean cubicles
- Look over key indicators to find outliers
- Clean the milking unit
- Other: (Textbox)

Is there another factor you think is equivalent important?

Textbox

Feeding

I the following questions we want you to answer what is true for the group you think is the best functioning group

What type of feed are you using?
What is before the "+" refers to the feed served in the feed bunk

- Total mixed ration + rewarding feed in milking unit
- Partly mixed ration + additional concentrate in milking unit and automatic feeders
- Only roughage + concentrate in the milking unit
- Only roughage + concentrate in the milking unit and automatic feeders
- Other: (textbox)

How many times per day is feed delivered in the feed bunk?

Textbox

How long is the greatest stop in feed delivery during night?
State as the number of hours

Textbox

Is the feed pushed forward in the feed bunk so that the cows easier can access it?

- No
- No, the cows can always reach the feed
- Yes, number of times per day: (textbox)

Which of the following feeding factors do you think is the most important to achieve a high production?
Rank the 2 most important, where 1 is the most important and 2 the second most important

- Feed is delivered often
- It is always feed in the feed bunk
- The feed should taste good and attract the cows
- The feed is adjusted after each individual cow's energy balance
- The feed in the milking unit should taste better than other feed

Is there another factor you think is equivalent important?

Textbox

Final question

Are you happy with your feeding strategy, cow traffic and routines or is there something you would like to change? Do you have anything to add concerning the questions in the survey?

Textbox

Appendix 2. Interview guide

Overview

- For how long have you had VMS?
- Are you happy with your VMS?
  - Have you always been?
- What have been the greatest challenges to reach a good production in VMS?
- What have been the most important factors to reach a high production in VMS?

Feed

- Tell me about your feeding strategy
- How often do you deliver feed? (Manually/automatic)
- Have you seen any relationships between feeding strategy and cow traffic?
- Have you had any other feeding strategy?
  - In that case: Why did you change?
- What feeding factors do you think is the most important for at good production?
- Are you happy with your feeding strategy?

Building

- What are your thoughts about placing of water, access of water etc?
- Are you happy with the barn layout?
- Are you happy with your traffic system?
- Is there something that you are not happy with?
- Is there something you have had made different if you had built the barn today?

Management

- What is your strategy with occupancy?
  - Do you have other animals than cows in the group? (Heifers/dry cows etc.)
  - How do you think occupancy affect the production?
- How do you work to use the capacity of the milking unit?
  - Which parameters do you think is most important to control the capacity of the milking unit?

- How do you use DelPro as a work took?
    - Which parameter do you think is most important to check?
    - Which interventions do you make when you find a deviating key indicators?
    - Do you think you have enough knowledge to take advantage of DelPro?
- Tell me about your strategy about fetching cows to the milking unit
    - Do you fetch cows or are you avoiding it?
    - How do you avoid fetching cows?
    - Why do you think some cows do not visit the milking unit voluntary?
- Are you milking all cows in VMS?
    - Do you feed a need for an additional milking system?
- What actions do you take when the number of milkings decreases?
- What do you do with cows that do not visit the milking unit voluntary?
    - Take them out of production, change settings, take to another milking system etc.?
- What in you work do you think differs from farms with lower production?
- What are you greatest inspiration to do changes? Consulters, salespersons, other farmers etc.?

Final question

- What is the strength on your farm?