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Lying time of dairy cows during the transition period depends on milking system and bedding.

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Abstract

The lying time of high yielding cows is crucial for maximizing milk production and their welfare. When lying down, cows will ruminate and the bloodstream to the udder is larger, which stimulates milk production. The average lying time at farms, according to previous reports, is around 12 hours, while high yielding cows should lie down for at least 14 hours. Automatic milking systems (AMS) allow cows to decide themselves how much time they spend on eating, lying and being milked. The hypothesis is, that they will spend more time on lying than cows housed at farms with a conventional milking system. With the use of sensors, the total duration of the lying time, the amount of lying bouts and the duration of the individual bouts were measured at 14 farms in the Netherlands, from April to June 2016, with conventional milking parlors (n=7) or an AMS (N=7). The farms had free stalls with deep litter bedding (N=5) or mattresses (n=9). The results showed that cows housed at farms with a conventional parlor had a longer total lying time (12.2h ± 0.13 (SEM)) per day during the experimental period than cows housed at farms with an AMS (12.08h ± 0.15) and had a higher number of lying bouts (6.7 ± 0.08 (SEM) vs. 6.4 ± 0.09 (SEM) with a shorter individual duration (122.3m ± 2.53 (SEM) vs. 127.1m ± 2.91 (SEM)) ($P<0.05$). The results of the transition period were split and showed that during the dry period, there is no difference in lying time between conventional and AMS farms: 13.07 ± 0.04 (SEM) vs. 13.12 ± 0.05 (SEM) hours per day. The difference in lying time up to day 6 after calving is 42 minutes where cows at AMS farms lie down for 10.4 ± 0.2 (SEM) hours and cows at farms with conventional parlors for 11.1 ± 0.11 (SEM) hours. From day 19 post-partum the difference in hours was 6 minutes, 10.69 ± 0.016 (SEM) hours for the conventional parlors and 10.59 ± 0.019 (SEM) hours for the automatic milking systems. Cows at farms with deep litter bedding had longer lying times than at farms with mattresses throughout the period studied (12.6 ± 0.14 (SEM) hours vs 11.8 ± 0.14 (SEM) hours). The results of this experiment, provides a new insight in the way that cows should be accommodated to optimize the production of milk and welfare status of the individual cow and can function as a standard for future commercial farms with building plans.

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Introduction:

In 1950 the 394.943 dairy cows in the Netherlands produced around 4000 liters of milk per year. Nowadays 1.045.941 dairy cows produce an average of 9442 liters of milk per year (CRV, 2016). This transition of our animals to athletes requires different needs. During the last 116 years a substantial amount of changes has been made concerning housing, quality of forage, management and genetic selection (Grant 2007).

Lying time of the dairy herd

When housed in a free-stall barn, cows show a typical regular day pattern concerning different activities. This time budget represents the response of the cow to her environment. In this way, the time devoted to certain activities can be a representation of quality of the farm's management and the wellbeing of the animals (Grant 2007). Table 1 shows the different activities and the time devoted to a particular activity per 24 hours. As for the lying time, the table shows that in a free-stall environment a dairy cow lies for 12 to 14 hours per day, which is corroborated by Fregonesi & Leaver (2002) who observed that when cows are kept under the optimal environmental conditions, cows lie down for 12 to 14 hours a day.

Table 1: Typical daily time budget for lactating dairy cows (Grant 2007).

Activity	Time devoted to activity per day
Eating	3 to 5 h (9 to 14 meals/d)
Lying/resting	12 to 14 h
Social interactions	2 to 3 h
Ruminating	7 to 10 h
Drinking	30 min
Outside pen (milking, travel time)	2.5 to 3.5 h

The time spent on a specific activity differs per individual cow. As can be seen in table 2, the top-10% of cows by milk production, spend more time resting, thus lying, than the average milk production cows. For the top-10% this is 14.1 hours a day, while for the average cows this is 11.8 hours a day. This is a total difference of 2.3 hours per day. Instead of resting, average cows spend more hours standing in alleys and perching in stalls (Grant 2007, Watters et al. 2013).

Table 2: Daily behavioral time budget for top-10% of cows by milk production and average milk production cows (h/d) (Grant 2007).

Activity	Top-10%	Average
Eating at manger	5.5	5.5
Resting	14.1	11.8
Standing in alleys	1.1	2.2
Perching in stalls	0.5	1.4
Drinking	0.3	0.4

There are several important factors that influence the lying time of cattle. Numerous studies showed that different housing systems have different effects on lying time of cattle, ruminating time and the synchronization of this lying time (Cooper, Arney, & Phillips, 2007; Fregonesi & Leaver, 2001; Haley, Rushen, & De Passillé, 2000). Cows that are housed individually in a large pen with matrasses have a longer period of lying than cows housed in

tie stalls (Cooper et al., 2007). However, herds that are housed in a straw yard system lie down for a longer period than herds that are housed in a cubicle system. When housed in straw yard systems cows lie down for 13,6 hours per 24 hours whereas cows housed in a cubicle system lie down for 12,7 minutes per 24 hours. This is a total difference of almost one hour in which cows lie down when straw yards are at disposal (Cooper et al., 2007; Fregonesi & Leaver, 2001). Thus, the way a herd is housed or managed, influences the total milk production of that herd as well as the welfare status.

Jensen et al. (2005) demonstrated that a random heifer, which is three months pregnant, lies down with an average of 13 hours under experimental conditions. The average of lying hours on many farms is around 10 hours (Wierenga & Hopster, 1990; Haley et al., 2001; Jensen et al., 2005). Haley et al. (2001) showed that when dairy cows are housed at farms with matrasses instead of concrete floors, the lying time increases to 12 hours per day: an additional 1.8 hours compared to the concrete floor. These studies indicate that the majority of cows have a lower lying time than optimal. This lower lying time withholds the cow from ruminating, as cows tend to ruminate more often during lying periods. Several studies showed that a high-yield cow should lie down for at least 13 hours (Cooper et al., 2007; Wierenga & Hopster, 1990). Fregonesi & Leaver (2002) observed a difference in lying duration between high milk yield cows and cows with an average milk production. This was confirmed by Grant (2004), who indicated that for each additional hour a cow is lying per day, resting and ruminating, the milk yield increases with 1.7 kg per day. This is shown in figure 1 (Grant 2007).

How lying behavior influences milk yield

Allowing the herd to rest and lie down seems to be of great importance not only for maximizing milk yield but at the same time for the welfare of the animal (Munksgaard & Simonsen, 1996; Munksgaard et al. 2005). When cows lie down, there is time for rumination

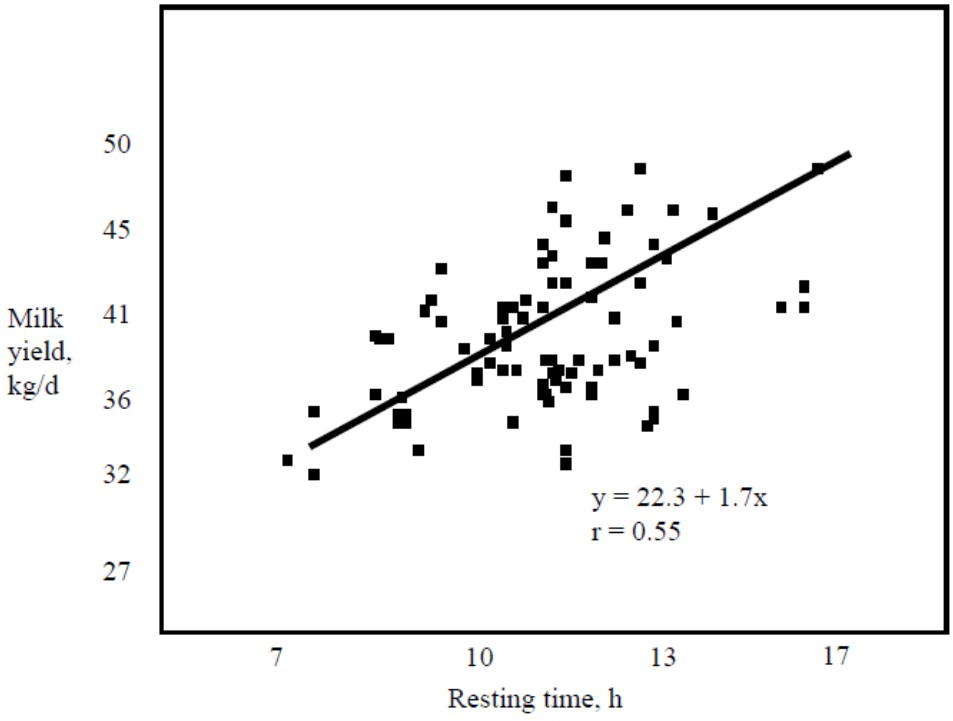

Figure 1: The relationship between daily milk yield per cow and time spent lying (Grant 2007).

and an increased blood flow to the udder, which positively contributes to the milk yield of the cow (Metcalf et al. 1992). When cows were prevented from lying down for 14 hours continuously, growth hormone concentrations in blood plasma decreased, which is associated with the production of milk (Munksgaard & Løvendahl 1993). Thus, when growth hormone concentrations in the blood decrease the production of milk will decrease as well (Haley et al., 2000, Arachchige et al. 2013). Munksgaard et al. (2005) demonstrated that above all behavior, lying time is the most important one, whereas lying had higher priority than eating. When cows were deprived of lying down they would subsequently spend more time on lying down afterwards rather than spending time on eating. For cows to take up abundant amounts of ration within a decreased period of time, the eating rate will be induced. Repeated periods of lying deprivation causes an increase in cortisol concentrations in blood plasma, which indicates that this is being experienced as stressful (Munksgaard & Simonsen, 1996; Cooper et al., 2007). Animals that are deprived of lying down can show discomfort by sniffing the ground, exploring the environment and shifting their weight because of lameness (Haley et al., 2000; Munksgaard & Simonsen, 1996). When the lying time is optimized, the cows will experience a higher status of welfare which indirectly, by an increased lying time, translates into an increase in milk production (Munksgaard & Simonsen, 1996; Haley et al, 2000; Grant, 2007). Together with the illustrated relationship between the time spent resting and the daily milk yield per cow, stimulating lying could maximize the production of milk on a farm.

The fact that lying is essential in the normal behavior of cows is cited in different studies. Metz (1985) showed that there is no difference between the average lying time of cows which were partly deprived of lying and cows that were not deprived. This means that cows that are deprived of lying will eventually catch up during the day. In addition, Krohn et al. (1993) discussed the effect of the amount of milkings during the day and the lying time. Groups that were milked twice a day and groups that were milked four times a day, had an equal average lying time. This suggests that the total duration of lying will not be influenced by the alteration of, for instance, the milking frequency.

The relevance of the amount and duration of lying bouts

Research shows that the amount of lying bouts and the duration of these bouts are important factors for the welfare of cows (Krohn et al. 1993; Tucker et al. 2004). For this reason, it is of great interest to study these aspects with the amount of data that is collected in the present study.

Gomez & Cook (2010) studied the lying time of 205 cows distributed among 16 different free-stall barns in the United States. They observed that cows lied down for 11,9 ± 2,4 hours which were divided into 12,9 ± 6,6 lying bouts of which each lying bout had a mean duration of 1,2 ± 0,4 hours. According to Österman (2001) the duration of one lying bout says something about the welfare status of the cow. When one lying bout has a duration of 90 minutes or longer this indicates a positive status of welfare while a lying bout of 15 minutes or less indicates a poor status of welfare (Österman & Redbo, 2001). When cows spend more time being milked, the duration of the individual lying bouts decrease and the amount of the lying bouts could increase. This, once more, indicates that spending a decreased amount of time on lying down, has negatives effects on the welfare of cows (Charlton, Haley, Rushen, & de Passillé, 2014).

There are many other factors that could influence the lying time of cattle. Cows that are lame will lie down for a longer period than healthy cows because standing is uncomfortable

(Walker et al. 2008). In this situation, an increased lying time would be a negative outcome. Besides lameness, the dry matter intake (DMI) is also associated with the lying time. A high DMI results in increased lying times, fewer bouts and an increased duration of the single bouts (Walker et al. 2008; Chapinal et al. 2009; Watters et al. 2013).

Stocking Density

An important factor in the lying behavior of cows is the stocking density (Anderson et al. 2014). Charlton et al. (2014) demonstrates that the lying behavior of cows is not significantly correlated with the lying behavior of cows. Nevertheless, cows at farms with a stocking density of 100% or less lied down for 12 hours per day or more. Cows housed at farms with a stocking density higher than 100% did not achieve these number of hours per day. In addition, Lobeck-Luchterhand et al (2015) showed that cows housed at farms with a stocking density of 80% spent more time on lying than cows that are housed at farms with a stocking density of 100%. A stocking density higher than 130% can cause an alteration in cortisol concentrations, lying behavior and ruminating activity (Krawczel et al. 2012). This confirms the importance of the stocking density at a farm for at least the lying behavior.

The automatic milking system

A change that dominates the attention of the farmer, besides the upcoming phosphate rights, is the main role that robotic milking plays at a growing number of farms (Holloway, 2007). This concept was first introduced in the Netherlands in 1992. Research showed that 25-30% of the farmer's time was spent on milking cows (Rossing & Hogewerf, 1997). With the introduction of the AMS, the farmer is no longer obliged to be present at milking times and can spend this time on monitoring animal health or heat detection (Jacobs & Siegford, 2012).

Jacobs & Siegford. (2012) found that the transition of a dairy herd to an AMS caused increased levels of stress for the cows during the first days. The novel milk unit and unknown sounds contributed to the increased vocalization, defecation and urination incidents during milking. Another important indicator of stress is the decreased milk yield found during the first four days. Overall, the cows adapted quickly to the AMS; as within a week, more than 50% of the herd was milked voluntarily. After a month 95% of the herd was milked voluntarily, which suggests that the herd became comfortable with the AMS (Jacobs & Siegford, 2012).

The downside of introducing an AMS is the trigger in social dominance of some cows. This could lead to prolonged waiting times in front of the AMS for cows lower in rank (Ketelaar-de Lauwere et al. 1996).

Aim of the study

The aim of the study was to demonstrate whether there is a difference in lying time between farms which use an automatic or conventional milking system. Besides the difference in milking systems, the difference between deep litter cubicles and matrasses will be part of the study. Herds that are being milked with an AMS can adjust their time schedule to the visits to the milking system, whereas herds that are milked in a parlor can't make this decision voluntarily. Because of this we expect that cows that are milked with an AMS have an increased lying time divided over a decreased number of lying bouts, compared to cows which are milked in conventional systems. These days it is possible to measure the time spent lying, amount of lying bouts and the duration of these lying bouts automatically with a sensor (Nedap, 2015). We used these sensors to determine the lying time on 14, farms with two different types of milking systems and free stall bedding.

Materials and Methods

Animals and farms

The data of 1281 cows (various breeds but mainly Holstein Friesian cows) was used for the determination of the lying duration, where the automatic milking group consisted of 451 cows and the conventional milking group of 830 cows. For the lying bouts, a total of 2395 cows were used for the collection of the data. All the animals were housed in a free stall housing system on 14 different dairy farms in the Netherlands which were randomly selected and thus represent the dairy industry in the Netherlands.

Seven farms used an automatic milking system and seven farms used a conventional milking system to milk their herd. Of these 14 farms five farms had deep litter cubicles (1 farm with an AMS and 4 farms with a conventional milking system) whereas nine farms had matrasses (6 farms with an AMS and 3 farms with a conventional milking system). The size of the herds varied between 110 and 300 animals per farm.

When cows were allowed outdoor grazing the information of the lying time was stored in the Nedap Smarttag for 24 hours and was transmitted to the antenna and reader, which were installed at the farms, when the herd returned.

The Nedap Smarttag-leg

To measure the activity and the lying time of the cow, they were equipped with sensors around the neck and one of the limbs, which used a G-sensor to sense the different movements. Movement is defined as an acceleration above a determined threshold. The Nedap Smarttag-leg were attached to the animals 6 weeks before calving and were removed 4 weeks after calving. The smarttag measured the lying time and sent the collected information to antennas which are installed at the farm. From the antenna, the data is sent to a process computer which converts the collected data to an excel sheet which can be displayed on the computer. After the data is converted into an excel document the proper information can be selected and corresponding charts and diagrams can be formulated by using the appropriate excel sheets (Nedap, 2015).

Data

During processing the data in excel, missing values were excluded from the data set. Missing values could occur due to interference of the antenna or due to miscommunication between the smarttag and the antenna or from the antenna to the process computer. Besides, the Smarttag stores the collected information for 24 hours. When the Smarttag is out of reach from the antenna for more than 24 hours (when cows were in pasture) the data collected in this time were erased.

The remaining data was used to calculate the average lying hours and bouts per day per milking system and type of bedding. With the use of these averages different graphs were plotted. Analysis was performed on the herds during the entire transition period and the postpartum period separately. The stocking density of the farms was calculated to determine if this was an explanation for the difference in lying behavior between the two milking systems.

Statistical analysis

In the present study two groups were compared with each other. First, the average amount of lying time (in minutes) between herds that were milked with an automatic milking system and herds that were milked in a conventional parlor. Second, the amount and duration of lying bouts between the automatic and conventional milking system groups. Finally, the lying times

of cows housed at farms with deep litter cubicles will be compared to farms equipped with matrasses, where the 95% confidence interval of the interaction between time and choice of bedding of the number of lying bouts was analyzed.

To analyze the data, the linear mixed model is used with cow as a random effect and time (in days), group, farm and bedding (cubicles or matrasses) as fixed effects. The normality was checked using a normal probability plot. For this IBM® SPSS® Statistics 24.0 was used.

Results:

Lying hours

The main goal in this study was to investigate the difference in lying time between cows housed on farms with an automatic milking system and cows that are housed on farms with conventional parlors.

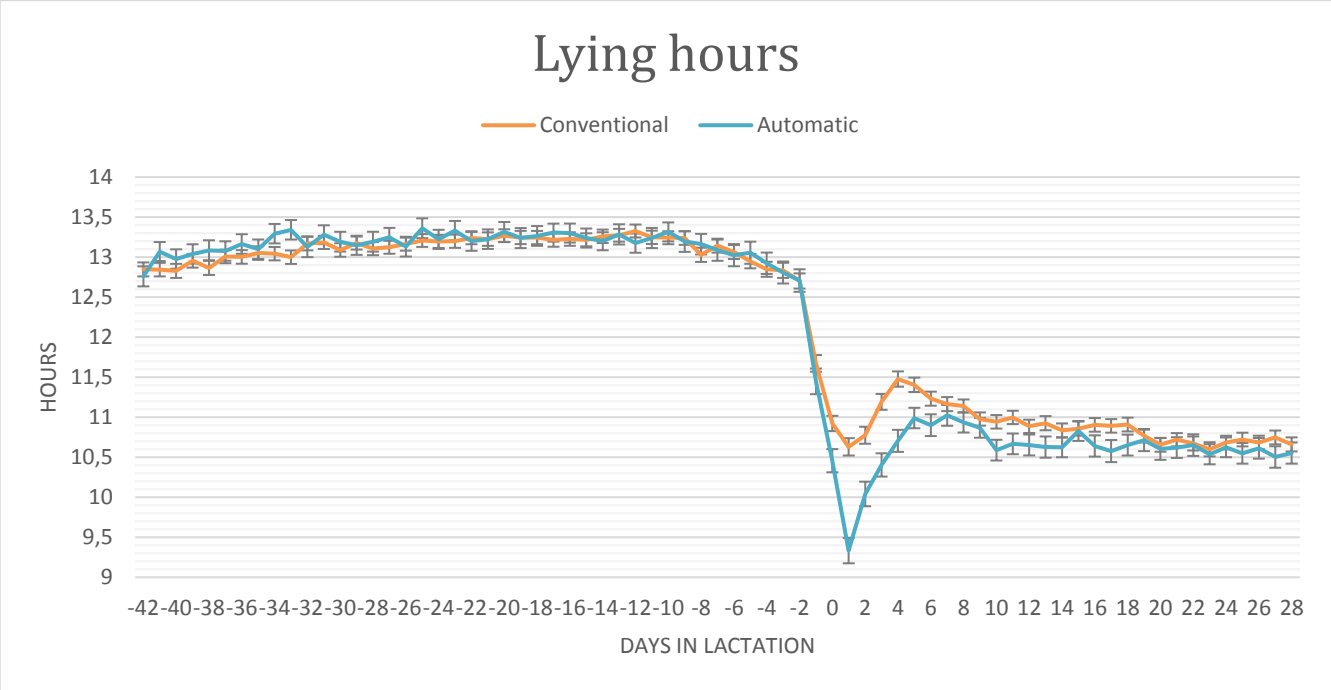

Figure 2: The lying behavior of cows (conventional n=830, automatic n=451) in hours with SEM during 42 days pre-partum up to 27 days post-partum where day 0 is the moment of calving.

As can be seen in figure 2, there is a minimal difference in lying hours between herds that are milked with the use of a conventional or an automatic milking system. Herds that were milked with a conventional milking system laid down for 12.2 ± 0.13 (SEM) hours per day during the entire period (42 days before and 27 days after calving), while herds that were milked with an AMS laid down for 12.1 ± 0.15 (SEM) hours a day. This means that the average cow on an average farm with a conventional milking system laid down 6 minutes more than on an average farm milking with an AMS during this period. During the dry period, 42 days before calving, there is no difference in lying time between conventional and AMS farms: 13.07 ± 0.04 (SEM) vs. 13.12 ± 0.05 (SEM) hours per day.

In figure 2 the x-axis represents the days in lactation. At first, the days before calving were taken in account which were not of interest when studying the lying behavior of producing cows. Figure 3 shows a more detailed situation of the lying behavior after returning to the lactating herd. This approach was chosen to study the difference in lying behavior between the different milking systems. As cows are not being milked in the dry period, this period is not the most interesting period to study. The amplification of figure 2 was made to focus on the difference, which is clearer in figure 3.

In the first week post-partum cows at farms with an AMS laid down for 10.4 ± 0.2 (SEM) hours and cows at farms with a conventional system laid down for 11.09 ± 0.11 (SEM) hours ($P<0.05$). In the second week, cows housed at AMS farms laid down for 10.77 ± 0.07 (SEM)

hours and cows housed at conventional farms laid down for 11 ± 0.04 (SEM) hours (P<0.05). For cows on a farm equipped with an automatic milking system there was a total average of 10.6 ± 0.06 (SEM) hours of lying during the 28 days post-partum, while for cows that are housed on a farm with a conventional milking system this was 10.9 ± 0.04 (SEM) hours. This is a significant difference (P<0.05; see appendix). Figure 2 shows that the cows housed at AMS farms had a deeper dip than the conventional milking system cows.

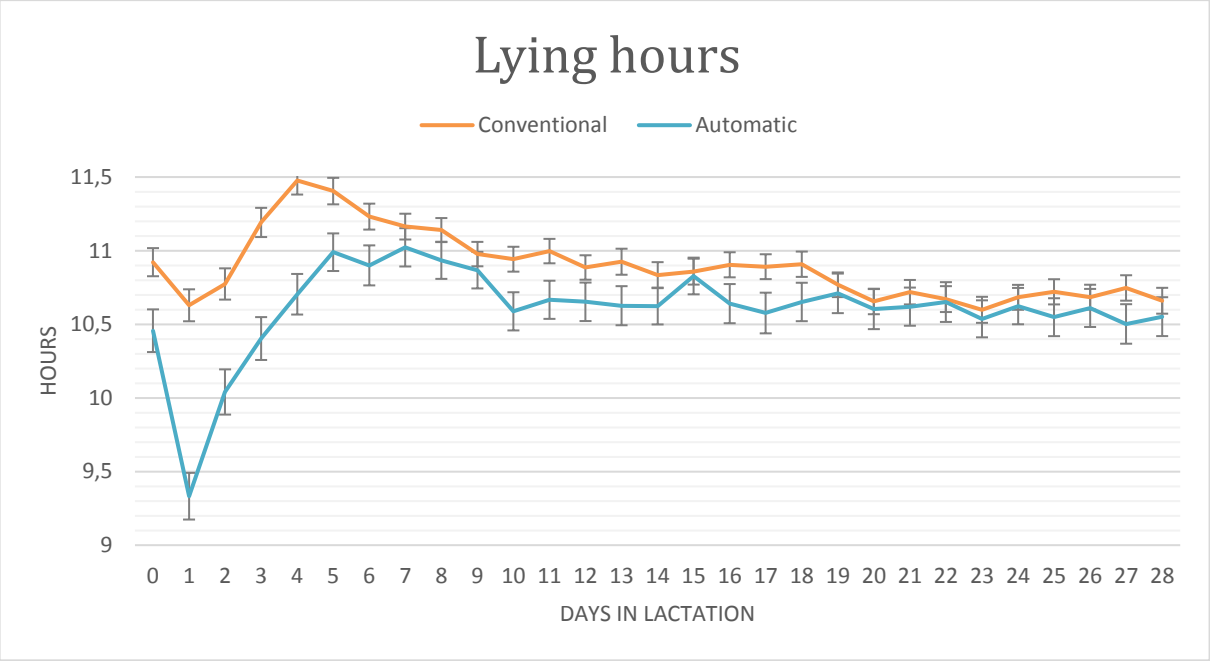

Figure 3: Lying behavior of cows (conventional n=830, automatic n=451) in hours where day 0 is the moment of calving.

In figure 2 and 3, a decline at day 1 can be seen. Figure 3 is an enlargement of figure 2, to concentrate on the period after calving, in which the cow returns to the lactating herd, and to show the difference more detailed. Compared to the total average during the 28 days in lactation (10.6 ± 0.06 and 10.9 ± 0.04), cows on a farm with an automatic milking system laid down for 9.3 ± 0.14 (SEM) hours on day 1 while cows on a farm with a conventional system laid down for 10.6 ± 0.1 (SEM) hours. For the first group of cows this is a difference of 18 minutes and for the second group this is a difference of 72 minutes on day 1 compared to the overall average. Herds on farms with a conventional parlor had a less deep decline in lying hours after calving than herds on farms with an AMS.

As can be seen in figure 3, there is a difference in hours lying down between cows housed at farms with an AMS and cows that are milked with a conventional parlor, up to day six after calving. During these days, cows on farms with an automatic milking system laid down for 10.4 ± 0.2 (SEM) hours while for cows that were milked in a conventional parlor this was 11.1 ± 0.11 (SEM) hours. This is a difference of 42 minutes.

Besides the difference in hours at the beginning of lactation, the stability of the last 10 days of the observation period deserves attention. From day 19 post-partum the difference in hours was 6 minutes, 10.69 ± 0.016 (SEM) hours for the conventional parlors and 10.59 ± 0.019 (SEM) hours for the automatic milking systems. At this moment, there is a minimal difference between the two milking systems, concerning the number of hours lying down.

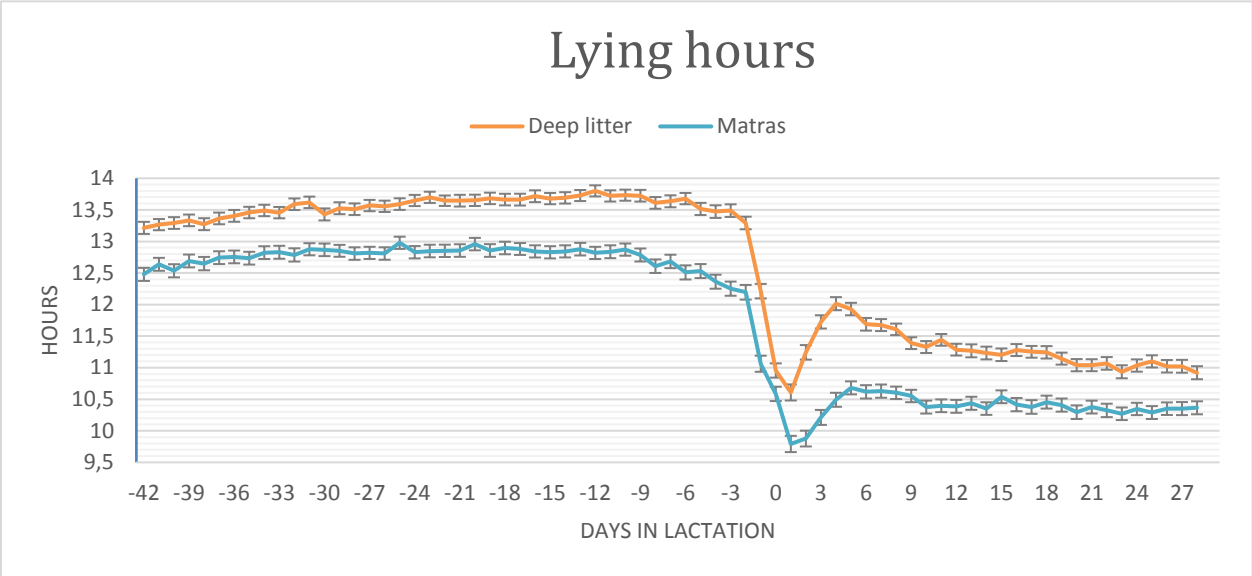

Figure 4: Difference in lying behavior between deep litter cubicles and matrasses (matrass n=689, deep litter n=591).

As can be seen in the appendix, there is a significant difference in the interaction: time (in days) * choice of bedding. This means, that the choice of bedding influences the lying time. As can be seen in figure 4, cows that have access to deep litter cubicles laid down more than cows that had to lie down on mattresses: 12.6 ± 0.14 (SEM) hours vs. 11,76 ± 0.14 (SEM) hours for the total observation period. When, after calving, cows returned to the lactating herd the lying time for cows at farms with deep litter cubicles was 11.3 ± 0.06 (SEM) hours. For cows at farms with mattresses this was 10.4 ± 0.04 (SEM) hours.

Lying bouts

As can be seen in figure 5, there is a difference in the amount of lying bouts between herds housed on the different types of farms. At farms with an automatic milking system the mean of lying bouts after calving, when cows returned to the lactating herd, was 7.0 ± 0.06 (SEM).

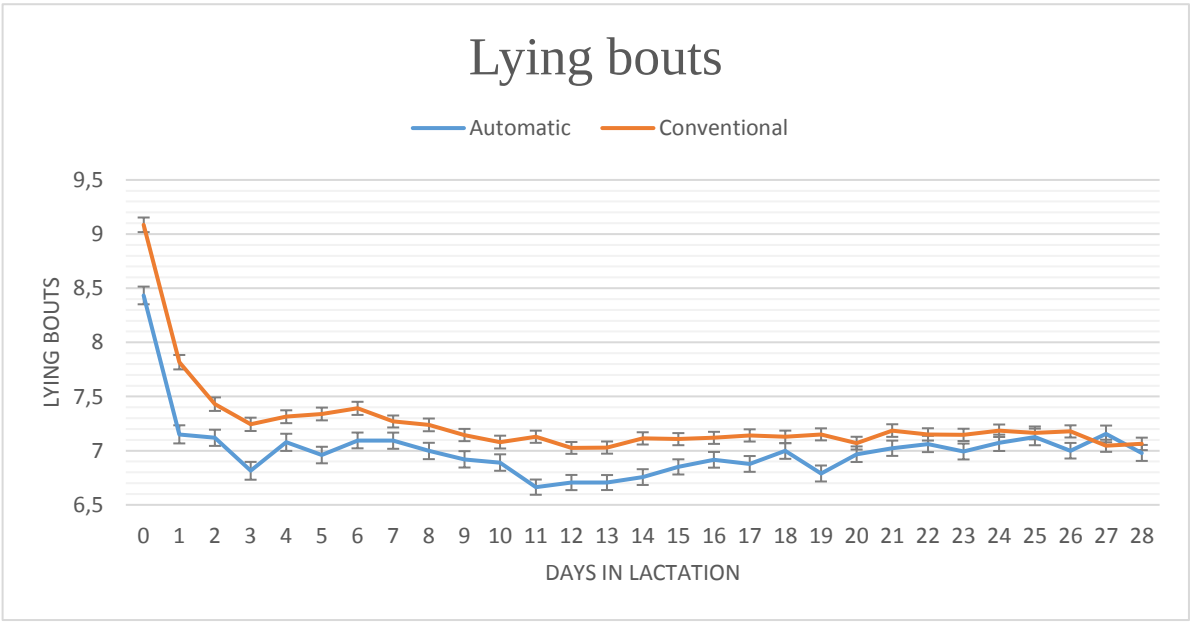

Figure 5: The average number of lying bouts where day 0 is the moment of calving (conventional n=1375, automatic n=1020).

For cows milked on a farm with a conventional milking parlor this was 7.3 ± 0.07 (SEM). This is a significant difference of 0.3 bouts (P<0.05).

On day 0 there was an elevated number of bouts which declined rapidly. The two lines follow a similar pattern during the first two days. As with the total lying hours, the number of bouts reached a stable average from day 10 onwards. During day 10 up to 28 the average amount of bouts was 6.9 ± 0.03 (SEM) for the farms with an AMS and 7.12 ± 0.01 (SEM) for the farms with a conventional parlor. They did not only reach a stable value, in addition they almost had an equal average amount of bouts.

Besides the amount of lying bouts, the duration of an individual bout has been calculated as well (figure 6). The average duration of an individual bout at a farm with an AMS was 101 ± 1.31 (SEM) minutes and for farms milking with a conventional parlor this was 99 ± 0.66 (SEM) minutes (P<0.05, see figure 8 appendix).

Compared to the overall trend of the two lines, the first days had shorter bouts. For the first three days, the average duration of a lying bout is 95.2 ± 5.24 (SEM) minutes for the AMS farms and 93.3 ± 3.34 (SEM) minutes for the farms with a conventional parlor, while for the remaining 25 days this was respectively 102.5 ± 1.01 (SEM) minutes and 100.2 ± 0.25 (SEM) minutes.

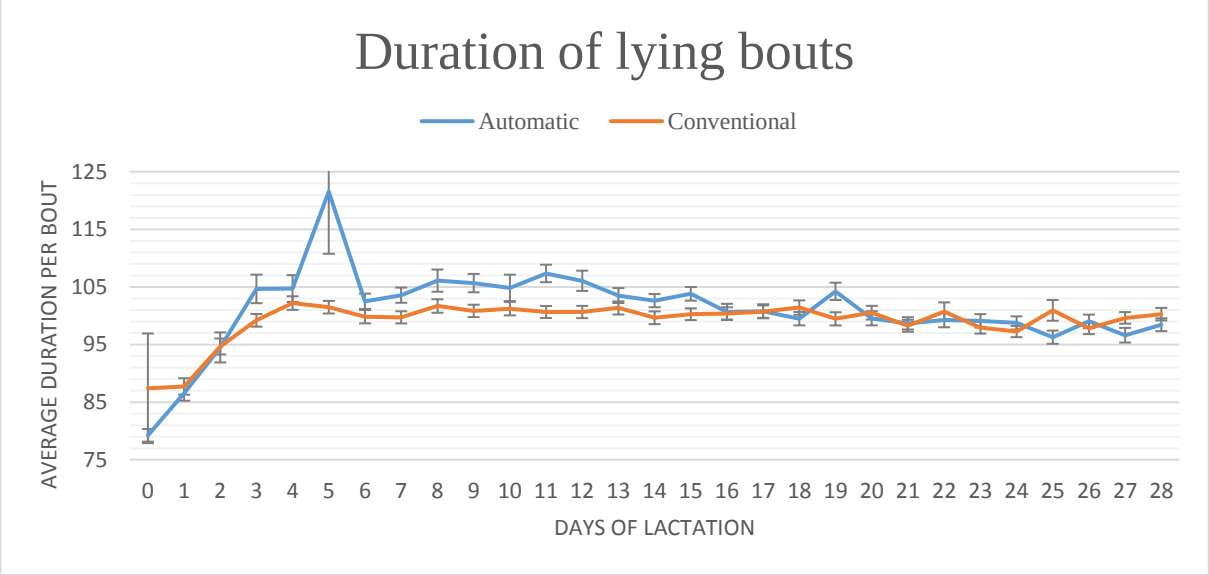

Figure 6: The duration of an average lying bout where day 0 is the moment of calving (conventional n=1375, automatic n=1020).

In figure 6, a peak during day 5 for the AMS farms can be seen. On day 5 the average duration of a lying bout on a conventional parlor farm was 101 ± 1.09 (SEM) minutes, while for cows on an AMS farm this was 121.5 ± 10.8 (SEM) minutes. This is a difference of 20 minutes on day 5. After day 6 the two lines each showed a stable follow-up. It is not known what caused this peak, it seems that all data on day 5 from the involved farms with automatic milking systems were higher.

The time spent lying, the amount of lying bouts and the duration of these, were correlated with the choice of bedding as can be seen in the appendix, figure 6. In table 3 the 95% confidence interval of this interaction (choice of bedding * number of lying bouts) is shown.

Table 3. the 95% confidence interval of the interaction between time and choice of bedding of the number of lying bouts.

	95% CONFIDENCE INTERVAL	
TIME (IN DAYS) *BEDDING	**Lower bound**	**Upper bound**
0	-,598102	-,123704
1	-,451653	,023069
2	-,472016	-,003629
3	-,605107	-,130658
4	-,630658	-,154655
5	-,647521	-,171755
6	-,837632	-,361629
7	-,832189	-,356685
8	-,929983	-,453326
9	-1,034223	-,558580
10	-1,060453	-,586410
11	-,901762	-,427720
12	-1,049241	-,573474
13	-1,087594	-,611648
14	-1,009394	-,533218
15	-1,159769	-,684845
16	-1,261794	-,787163
17	-1,194740	-,718370
18	-1,255833	-,780159
19	-1,230093	-,755530
20	-1,181716	-,706086
21	-1,264905	-,789263
22	-1,329390	-,853354
23	-1,218755	-,742245
24	-1,346441	-,868570
25	-1,366278	-,888569
26	-1,290526	-,812593
27	-1,496054	-1,017878
28	-1,462475	-,982732

Table 3 shows that the choice of bedding on a farm makes a difference in the amount of lying bouts. Secondly, the interaction between time (in days) and the choice of bedding became more important during the four weeks as can be concluded from the increasing bounds of the confidence interval. Besides the amount of lying bouts, this was consistent for the lying time (in minutes). The difference between the 95% confidence interval increases from day 0 to 28. This means that the choice of bedding became more decisive during the time after calving. This table was included to show the extensive effect of the choice of bedding on the lying behavior of cows.

Discussion

As stated in the introduction, lying time is important in high yielding cows for a maximum production and welfare.

The results of the present study show that cows housed at farms with a conventional parlor, lie down for a longer period than cows that are housed at farms with an AMS during the first 2 weeks post-partum (P<0,005). Before the start of this experiment, the idea was that cows at farms with an AMS should lie down for a longer time because of the free time management of these cows and the reduction in waiting time in front of the parlor. The results show a different outcome, which will be discussed in this section. The fact that the present study included several different farms that are commercial enterprises located in the Netherlands, makes that the results are valuable for relating the results to practical advices.

The difference in lying time between the two milking systems is bigger during the first days after calving than the difference around, for instance, day 25. This can be a consequence of the fact that cows are moved back to the herd after they calved. The newly introduced cows have to integrate in the current herd hierarchy. When milking with a conventional parlor, the farmer makes sure that all the cows are gathered and milked. This situation is different when cows have to, voluntarily, visit the AMS and some cows, higher in hierarchy, prevent them from visiting the AMS. In addition, farms that milk with a conventional parlor will know structural patterns during the day, for instance the moments of milking. For farms that installed an AMS, cows should adjust their visits to the AMS to the environment. When the AMS is already occupied, this can intervene with the time schedule of the cow and can again be accompanied by stress and decreased lying times.

It could be possible that the introduction of an AMS will lead to difficulties as a strong social hierarchy among cows prevails, as already stated in the introduction. Cows that are high in rank will cause prolonged waiting durations for cows lower in rank. These cows will be waiting in front of the AMS instead of lying down and ruminating (Ketelaar-de Lauwere et al. 1996). On the other hand, cows that are higher in rank will have reduced wainting times and are able to lie down for a longer period. On average this could lead to reduced waiting times for cows at farms with an AMS, which is not what the results of this study suggests.

The fact that the difference in lying time decreases during the 28 days after calving, makes it less likely that social hierarchy is the main reason for the difference in lying time. On day 25, as mentioned above, there is a social hierarchy as well, while the difference in lying time is minimal. For this, social hierarchy presumably plays a minor role in the lying time in this study.

Charlton et al. (2014) state that the stocking density and the time before milking are two crucial factors in the reduction of the total lying time. When there are more animals than places to lie down, the average duration of lying down will decrease. In the present study, the average density during the experiment for AMS farms was 0.89 ± 0.1 (SEM) and for conventional farms 1.02 ± 0.1 (SEM). This suggests that there was a higher stocking density in farms with a conventional parlor, which does not correspond with the lying data from this study. The expectation is that cows on farms without an overstocking, have more opportunity to lie down and do not have to compete for cubicles. In the present study cows at AMS farms have more space and cubicles to lie down but still do not lie down as much as cows at conventional farms (see figure 3).

Thus, as stated above, stocking density is not the major reason for the difference in the lying behavior in this study. This might, partly, be explained by the fact that an automatic milking system has a fixed capacity. Stocking cows is not profitable because they cannot be milked because of the capacity of the system. For a farmer to house more cows, an extra milking system should be purchased. When farms have a milking parlor, the number of cows is not a limiting factor. The farmer only spends more time on milking more cows. This could be a reason why farms with a conventional milking parlor have a higher stocking density than AMS farms.

On the contrary, the data from the stocking density is not entirely reliable. The stocking density is calculated from the number of cubicles through a survey. Some inconsistency could be found in the answers as the study includes farms which divide the lactating cows into groups (high or low milk yield e.g.) which can be influenced by the number of cows that will calve in a specific time frame. The number of cows was taken from a monthly registration system in which all lactating cows are included. However, this number of cows fluctuated during the experimental period. Thus, the stocking density could nevertheless be a cause for the difference in lying time. Unfortunately these data were not properly recorded during the study period.

When the stocking density is not the major cause for the difference in the lying time, another aspect could have influenced the difference in lying time. Besides the stocking density, the space that cows have per cubicle is another important feature. When the dimensions of the cubicles do not meet the dimensions that the cow needs, another sort of stocking density occurs. When cows with a big body volume and long feet lie down in one cubicle, she will place parts of her body on sections of a next cubicle. This makes it impossible for other cows to lie down in that particularly cubicle. The dimensions of the cubicle and other additions, for instance the neck rail or brisket locator, can be a cause for cows to adjust their lying behavior. When standing up or lying down lead to painful experiences because of inaccurate dimensions of the cubicles, cows will try to avoid lying down or will spend less time on lying (Tucker et al. 2004; Anderson 2014). Choice of bedding may be an important factor in the lying behavior of cows but the dimensions of the individual cubicles have to correspond as well.

As already presented in the results, the choice of bedding is an important factor in the lying time. Drissler et al. (2005) showed that the depth of the litter determines the duration of the total lying time. The deepest litter was around 19 cm while this was compared to cubicles with 10 cm of litter. Cows that lay in cubicles with 19 cm of litter had an increased lying time; 1.15 hours longer than cows that laid down in cubicles with less litter. Together with the results we found in the present study (see figure 4), this strongly suggests that the choice and depth of the litter is crucial in the lying time of cattle. In addition, table 3, showing the 95% confidence interval of the interaction time * choice of bedding, showed that the choice of bedding becomes more important as time passes ($P<0,005$). Where the lying time reaches a steady state with the different milking systems, the difference in choice of bedding continues, even after two weeks. As the choice of bedding is crucial in the lying time, this might be more important than the difference in milking system.

Conclusion

Thus, cows that are housed at farms that milk with a conventional parlor lie down more than cows that are housed at farms with an AMS and have an increased number of lying bouts compared to cows housed at AMS farms. The difference in time for the individual lying bouts is minimal from day 25 onwards. As for the time cows spend on lying and the amount of lying

bouts, the difference between milking with an automatic milking system or a conventional milking system is significant during the first 2 weeks post-partum, but the choice of bedding showed an interaction over time, suggesting that this choice of bedding is an important factor in the lying time of cows as the 95% confidence interval increases with time (see table 3). With the results of this study it can be concluded that a deep litter cubicle is the best option for dairy cows in the Netherlands as it optimizes the lying behavior of cows but also decreases the number of cows that are lame. This contributes to the overall welfare of the cow but also to the job satisfaction of the farmer. For these reasons, all new constructed farms should be equipped with deep litter cubicles.

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Appendix

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	844,142	40225,230	,000
Groep	1	36006,348	131,161	,000
Tijdindagen	28	35471,517	11,886	,000
Bodembedekking	1	32114,672	782,330	,000
Tijdindagen * Bodembedekking	28	35471,500	5,364	,000

a. Dependent Variable: Aantal minuten liggen.

Figure 2. ANOVA table of the results for the lying behavior in minutes. Acquired from SPSS

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	38640,000	307922,155	,000
Groep	1	38640,000	621,748	,000
Tijdindagen	28	38640,000	35,312	,000
Bodembedekking * Tijdindagen	29	38640,000	37,513	,000

a. Dependent Variable: Aantal bouts.

Figure 3. ANOVA table of the results from the lying bouts. Acquired from SPSS

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	603,804	1710,252	,000
Bodembedekking	1	4335,769	497,183	,000
Groep	1	4239,485	116,085	,000
Tijdindagen	28	21678,609	3,953	,000
Bodembedekking * Tijdindagen	28	14218,583	2,408	,000

a. Dependent Variable: Duration bouts.

Figure 4. ANOVA table of the results from the duration of the bouts. Acquired from SPSS