Estimating economic and production losses in relation to locomotion score in primiparous Polish Holstein-Friesian cows

Paweł Zółkiewski a, Waldemar Teter a, Ewa Janus b, Piotr Stanek b, Ewelina Flis a, Andrzej Bochniak c, Monika Różańska-Boczula d and Witold Chabuza a

a Sub-Department of Cattle Breeding and Genetic Resources Protection, Institute of Animal Breeding and Biodiversity Protection, University of Life Sciences in Lublin, Lublin, Poland; b Unit of Organic Food Production of Animal Origin, Institute of Animal Breeding and Biodiversity Protection, University of Life Sciences in Lublin, Lublin, Poland; c Department of Applied Mathematics and Computer Science, University of Life Sciences in Lublin, Lublin, Poland

ABSTRACT
The aim of the study was to determine the effect of the free approach to automatic milking system of primiparous (PP) Holstein-Friesian cows with varying locomotion score on the milking frequency, yield per milking and daily milk yield in the subsequent phases of lactation, and the consequent production and economical losses. The evaluation of cows’ locomotion was successively repeated in seven consecutive months, using a five-point scale of posture and movement assessment. It has been found that in the case of analysed PP cows with the locomotion score 4 led to reduction in the milk production by 11% in third stage of lactation compared to the healthy PP. PP cows with locomotion score 4 less frequent went to milking robot and was characterized by the lowest daily milk production.

Introduction
Lameness in dairy herd cows is an important problem for animal health associated with pain and welfare, but it also causes a reduction in the milk production and reproductive efficiency (O’Callaghan et al. 2003; Cha et al. 2010). If the lameness is not severe, cows are kept as productive animals, but the reduction in the milk production and reproductive problems imply the reduction in income and also cause not measurable economic losses. An increase of lameness degree may affect a shorter productive life, which in turn generate an increase of measurable economic losses (Dunthorn et al. 2015).

According to the literature, lameness is ranged between 6 and 42% of the total dairy cow herds (Dembele et al. 2006; Barker et al. 2010; Ito et al. 2010; Tadich et al. 2010; Sogstad et al. 2012; Von Keyserlingk et al. 2012; Van Nuffel et al. 2015). Amory et al. (2006) and also Cooke and Bennett (2005) reported that of the whole (21.5 million) EU dairy cow population, about five million had problems with locomotion, which in terms of costs amounts to more than a billion EUR per year.

According to many authors, lameness causes significant losses in the milk production ranging from 270 up to 857 kg per lactation (Hernandez et al. 2002; Amory et al. 2008; Bicalho et al. 2008; Gudaj et al. 2012). In turn, Onyiro et al. (2008) estimated milk production losses between 0.78 and 5.5 kg per day, depending on the level of lameness.

Prevention or early diagnosis and treatment of lameness in cows at all stages of lactation should be part of the practical management of cows’ herd (Sulayeman and Fromsa 2012). Currently, an increasing number of herds is milked in Automatic Milking System (AMS) with free milking access. The reluctance of cows to move is of increasing importance for the organization of work and production results. Chronic stress may affect the welfare of the cow, and acute stress during milking can decrease milk yield. Therefore, it is important to quantify if and how long stress during adaptation to an AMS might persist (Jacobs and Siegford 2012a). Automatic milking systems have the potential to increase the milk production by up to 12%, decrease labour by as much as 18%, and simultaneously improve dairy cow welfare by allowing cows to choose when to be milked. However, producers using AMS may not fully realize these anticipated benefits for a variety of reasons. For example, producers may not see a reduction in labour because some cows do not milk voluntarily or because they have not fully or efficiently incorporated the AMS into their management routines (Jacobs and Siegford 2012b).

The aim of the study was to determine the effect of free approach to AMS of primiparous (PP) Holstein-Friesian cows with varying locomotion score on the milking frequency, yield per milking and daily milk yield in the subsequent phases of lactation, and the consequent production and economical losses.

Materials and methods
Description of the herd
The study was conducted in a herd of Black and White variety of Polish Holstein-Friesian dairy cows, amounting 102–150 heads (depending on the month of observation). Cows were...
maintained in a loose standing cowshed with slatted, concrete floor of a joist width of 100 mm and a space width of 25 mm. Slatted floor was cleaned regularly every 4 h by an automatic robot pushing impurity to a tank placed under the building. Bedding positions (boxes) were lined with rubber mats covered with lime.

Cowshed was equipped with an AMS, i.e. two milking robots, with free access for milking and fixed time between successive milkings. Cows with exceeding 12-h interval between milkings were herded for milking by the service. Only entrance to the robot completed by milking was taken into account. The average daily yield of cows in the experimental period was 26 kg of milk.

**Observation methodology**

The study included from 77 to 108 PP, depending on the month of observation. The evaluation of cows’ movement (locomotion) started on 28 December 2016, and it was gradually repeated in monthly intervals in the next seven repetitions. Each evaluation was performed by one trained person. The animals were observed during the movement in order to detect any abnormalities in locomotion and while standing in order to detect posture abnormalities. A five-point scale of posture and movement assessment (LSc – locomotion score) developed by Sprecher et al. (1997) was used to evaluate the locomotion of cows.

**Methodology of data collection and estimating of losses**

To assess the effect of locomotion disorders on production parameters, data from a computer system to a herd management were used. Daily yield, yield per milking and daily frequency of milkings were established taking into account the partial results from three days before and three days after assessment in order to avoid accidental result on any given day.

In 665 partial results of locomotion evaluation, in which healthy cows constituted 32% (213 observations, score 1), 49% – with subclinical lameness (326 observations, score 2), 16% – with moderate lameness (106 observations, score 3) and 3% – with severe lameness (20 observations, score 4). Cows with score 5 had not been found.

Using real data from an automatic system to herd management, daily economic losses per 100 lame cows resulting from the reduction of milk production by cows with lameness compared to healthy animals were estimated. Difference between the average milk yield of cows with diagnosed lameness and fully healthy cows, being in the same period of lactation, was considered as the loss. The calculations were made separately for three periods of lactation. Milk losses have been expressed in kilograms and also financially in PLN and USD. The financial value of milk losses was calculated taking the average price of 1.50 PLN (Polish zloty) per kg. Determining the amount in USD (US Dollar) exchange rate of PLN/USD was accepted 3.63 for the period of research conducting (seven months), as the average rate of National Bank of Poland (NBP – Narodowy Bank Polski).

The daily loss in milk yield per one lame cow in each group of animals with a given score of locomotion and in each lactation period in reference to groups of healthy animals was estimated by the formula:

\[ L(i, j) = \begin{cases} a_{i1} - a_{ij} & a_{i1} > a_{ij} \\ 0 & a_{i1} \leq a_{ij} \end{cases} \ (\text{kg}) \]

where \( i \) is the index corresponding to the number of lactation period \((i = 1, \ldots, 3)\); \( j \) is the index corresponding to locomotion score \((j = 2, \ldots, 4)\); \( a_i \) is the average milk yield in group cows in \( i \)th lactation period and \( j \)th locomotion score. The total daily losses for each group of lame cows are as follows:

\[ \text{Loss}(i, j) = L(i, j) \cdot n_i \ (\text{kg}) \]

where \( n_i \) is the average number of cows in \( i \)th lactation period and \( j \)th locomotion score.

Daily losses generated per 100 lame cows were estimated using the formula:

\[ \text{Loss}_{100}(i, j) = \text{Loss}(i, j) \cdot 100 \ (\text{kg}) \]

**Statistical analysis**

The following factors were statistically analysed: number of daily milkings (milking frequency), the yield per milking and daily milk yield. Due to the nature of the experiments, a mixed model was used with repeated measurements, which concerned consecutive observations performed on the same cow. Both score of locomotion as well as the stage of lactation were considered as qualitative variables; in addition, the score of locomotion was included as a random factor. Cows were divided into three lactation stages (≤100 days, 101-200 and > 200 days of lactation) and 4 scores of locomotion. The analysis included the possibility of interactions between lactation stage and the score of locomotion. If significant statistical differences were found between the estimated means, the Tukey-Kramer multiple comparison test was used. Thus, the information was obtained for which groups significant statistical differences occurred. The level of significance was set at \( a = 0.05 \). Statistical analysis was performed using SAS software version 9.3 (2011).

**Results**

**Milking frequency**

Based on the results of the statistical analysis (Table 1), it was shown that both factors significantly affected the average number of milkings in the PP cows: locomotion score \((p = .0104)\) and stage of lactation \((p = .0157)\). In contrast, the interaction between these factors \((p = .2602)\) proved to be statistically insignificant. PP cows of locomotion score 1 most often approached the AMS for milking (on average 2.38 times), while the least frequently those diagnosed with locomotion score 4 (2.10 times). Considering the lactation stage, cows in the third lactation stage the most frequently used the milking robot (2.37 times), compared to 2.14 times in the first lactation stage.
As a result of multiple comparisons of the values obtained for group pairs, it was found that cows with LSc 1 and 4 significantly differed (p = .0143). For other pairs of means, statistical differences (at a significance level α = 0.05) were not detected, although in some cases, p values were low (for the LSc 1 and 3 p = .0903, and for 2 and 4, p = .147). Regarding the lactation stage, statistical differences (p = .0111) were confirmed between the first and third periods. The maximum difference between the number of daily milkings for cows with normal locomotion – score 1 (2.38), and identified cases of strong lameness – score 4 (2.10) was 0.28. As it is shown in Table 1, the differences between various subgroups divided both by the stage of lactation (columns) and the locomotion score (rows) were statistically significant in many cases.

It was shown that with the passage of lactation cows with LSc from 1 to 3 showed an increased frequency of milking in AMS. Considering the lactation stage and the score of locomotion, PP cows in the first lactation stage milked the least often (2.07–2.26), while most often those in the third lactation stage (2.16–2.44).

### Yield per milking

Analysing the effect of LSc and lactation stage on the volume of a single milking (Table 1), we showed statistically significant differences in both factors analysed, i.e. the LSc (p = .0079) and LSt (p = .0011) as well as their interaction (p = .0054). The highest yield per one milking was recorded in cows with locomotion scores 2 and 3 (9.37 and 9.35 kg, respectively), while the lowest volume of a single milking was found in cows with locomotion of the 4th score (8.73 kg). With respect to lactation stage, a decreased productivity per milking was recorded from 9.69 kg in the first stage of lactation to 9.03 in the second (p = .0165) and 8.59 kg in the third (p = .0007). Yield per milking of healthy PP cows (score 1) in all periods of lactation was at a similar level of 8.91–9.05 kg of milk. The largest decrease (17%) in a single milking volume (7.90–9.56 kg of milk) was found in PP cows with severe lameness (score 4).

### Daily milk yield

Based on the results of the statistical analysis (Table 1), statistically significant differences were found in the daily milk yield of cows for both factors considered, i.e. the score of locomotion (p = .0029) and the lactation stage (p = .0148) as well as interactions among these factors (p = .0008).

The lowest daily yield was obtained for cows with severe lameness (score 4) (20.82 kg), while similar milk yield was found for the cows from groups 1 to 3 (22.67–23.00 kg). The Tukey–Kramer test confirmed significant differences of mean daily performance between the group with the fourth LSc and score 1 (p = .0173), 2 (p = .018) and 3 (p = .0088).
With regard to the lactation stage, statistically significant differences in daily performance occurred in cows in the first period – 23.25 kg of milk, compared to the second period – 21.85 kg of milk ($p = .015$) and the third – 21.79 kg of milk ($p = .0328$). As in the case of yield per milking, the highest difference in daily milk yield between the first and third periods of lactation was found in cows with LSc 4 (22.54 vs. 20.12–11%).

**Losses in production**
The daily losses in milk production (Table 2) in PP cows with impaired locomotion generated by 100 lame cows was estimated at 129 kg average. These losses were increased by 32 kg of milk in cows with LSc 2–283 kg of milk in cows with LSc 4. Lame cows in the first 100 days of lactation did not generate milk losses, while in the next two phases (second and third lactation stages) the losses of milk were 161.33 and 96.67 kg, respectively. Higher average milk yield for cows with lameness than for healthy cows in first 100 days of lactation can be explained by the fact that lameness more often affects high-yield cows. Estimated economic losses ranged from PLN 15 to 490 ($4–135 USD) depending on the score of locomotion and the lactation phase.

**Discussion**

**Milking frequency**
The lower frequency of entering the AMS was a significant problem occurring in PP cows with LSc 3 and 4 compared to healthy animals (Table 1). The resulting differences between the groups deepened with the progression of the hoof diseases. Healthy PP cows milked 11.8% more often than those with a severe lameness (score 4) and 5.5% more often than those with score 3 of locomotion. The results corresponded with the information provided by Bach et al. (2007). Miguel-Pacheco et al. (2014) also noted less frequent visits to AMS by cows with lameness in comparison to healthy animals, especially during night hours. It can be said that lame cows are less likely to visit the AMS due to a reduced comfort of walking and standing. Gleeson et al. (2007) paid attention to the risks arising from such a situation. They are connected with a discomfort of high udder filling, high pressure and an increased risk of infection.

Important information for farmers is the reduced frequency (by 3.4%) of milking of cows without obvious signs of lameness (score 2), compared to score 1. The obtained information confirms the need to pay particular attention to these cows to monitor the health of their limbs and eliminate (or limit) the exacerbating lameness. Gleeson et al. (2007) pointed out the fact that cows with varying scores of lameness, kept in barns equipped with milking robots (AMS), were milking less frequently, which was caused by the discomfort associated with standing and movement.

The beginning of each lactation (first 100 days) is a difficult period for PP cows for many reasons. The increasing milk production results in a high risk of metabolic diseases or udder inflammation. In addition, PP cows during this period are accustomed to entering the AMS.

It was found that (Table 1) PP cows in the first stage of lactation approached AMS for milking less frequently (by 5.7%) than in the second lactation (100–200 days) and by 9.7% less frequently than in the third period (>200 days). Therefore, it has been shown that with higher milk yields of PP cows, the frequency of entering AMS was also increased. In the first lactation stage, the decisive factor for the frequency of entering the robot was the service, as PP cows were getting accustomed to automatic milking. At this time, all the cows quite regularly entered the AMS. In the second stage of lactation, pain while walking limited the frequency of milkings, which decreased with the progressing lameness. Chapinal et al. (2009) and Ito et al. (2010) observed in cows with lameness longer lying time (18–72 min), decreased number of lying periods per day (0.1–1.7 times), and extended single rest periods (2–22 min), which they mainly explained by the reduced motor activity of lame cows. In the third phase of lactation (over 200 days), PP cows quite regularly approached AMS, with the exception of animals with locomotion score 4. It is difficult to interpret the relationship between milking frequency and LSc with respect to scores 1–3. Only in score 4, we could confirm this relationship in all periods of lactation because it was quite easy to find and interpret.

**Yield per milking**
Cows suffering from a pain in the limbs usually are reluctant to move, which, in turn has an impact on fewer milking visits, and this results in higher one-time milk quantities compared to healthy cows (Table 1). Only cows with score 4 gave less milk than the remaining subjects (scores 1, 2 and 3). This resulted from the forced entries into the robot, despite the not fully filled udder, when computer indicated exceeding a predetermined time between milkings. These cows were a source of additional work.

According to many researchers, deterioration of cow motility causes a decrease in daily milk yield even at 4–8 weeks before noticing lameness (Olechnowicz and Jaśkowski 2010; Reader et al. 2011; Van Hertem et al. 2013). In addition, these authors found that cows with a slight lameness (score 3) were the most productive animals in the herd.

Healthy cows (score 1) gave a similar amount of milk in a single milking in all the three periods of lactation. The average milk yield per milking of PP cows with second and third LSc in the first lactation stage (up to 100 days) was by about 1 kg of milk higher (ca. 10%) and cows much less frequently approached the AMS than in other periods of lactation. A sudden reduction was found in the milking volume of cows with LSc 2 and 3, particularly in the second lactation stage (10–6.5%). Animals with a severe lameness (score 4) in the first stage of lactation had a higher milking yield than healthy cows and lower than those with LSc 2 and 3. However, in subsequent periods of lactation, the highest reduction in yield of single milking was found in this group with respect to the first lactation stage (8.7–17.4%).

**Daily milk yield**
Taking into account the impact of LSc on daily milk yield it was observed that the highest productivity was demonstrated by
the cows with scores 2 and 3. A marked decrease was also shown in the productivity of cows with score 4 (Table 1), which clearly showed that occurrence of severe lameness has caused a reduction in individual milk production and the consequent production losses.

Reader et al. (2011) and Van Hertem et al. (2013) came to similar conclusions. In their study, cows with third LSc were characterized by the highest milk yield but their lactation curve declined quite quickly. Similar observations were also made by Olechnowicz and Jaśkowski (2010). Olechnowicz and Jaśkowski (2010) in addition to a decrease in milk yield, also found a reduction in fat protein and lactose content and an increase in somatic cells in milk with increasing locomotion score.

The daily milk yield of cows with varying LSc in different periods of lactation indicates a negative effect of the limb diseases on the course and persistence of lactation. Healthy cows had lower daily milk yield in the first postpartum period (up to 100 days). Then the yield increased, to gradually decrease in the third stage of lactation. A characteristic trait of cows with locomotion scores 2 and 3 was higher daily milk yield in the first lactation stage and then a sharp decrease in the production below milk yield of healthy cows in the subsequent phases of lactation. Cows with locomotion score 4 demonstrated significantly lower daily milk yield in later stages of lactation (10.7–12%). Considering the course of lactation in PP cows with successive LSc, it was found that lactation curve was not normal, i.e. sudden reduction in productivity in the second period and slowed down of the decline in the third stage of lactation. Reader et al. (2011) pointed out that cows, which showed an improvement in limb health (back to score 1), increased their performance after about four weeks from observable improvement in locomotion. In turn, Onyiro et al. (2008) showed a negative correlation between milk yield and the degree of motility and susceptibility to digital dermatitis as well as a positive correlation between the fat content in the milk and locomotion and a negative correlation with susceptibility to digital dermatitis.

Losses in production

Effect of lameness was a reduction of milk production, and therefore potential decline in farm income. The size of these losses was determined by the unit scale of production decline in cows with subsequent LSc and their number. In the analysed farm with AMS daily losses due to reduced milk production generated by 100 lame cows amounted to over PLN 190, which was giving $ 53.31 (Table 2).

In the present study (Table 1), the largest decreases in milk production were noticed between the BP with scores 3 and 4 of locomotion (8% – 1.9 kg). This is particularly crucial because it testifies about disease progression and potential time of its duration. Bach et al. (2007) concluded that with AMS, lame cows will result in a greater milk loss than in traditional milking parlours, as a consequence of a reduced milking frequency. In addition, a further economic loss generated by lame cows with AMS will be associated with the additional labour needed to fetch them. Green et al. (2002) stated that lame cows produced by 1.12 kg less milk per day, however, Bicalho et al. (2008) by 3.1 kg, in comparison to healthy animals. In turn, Alawneh et al. (2011) reported that cows with lameness got pregnant averagely 12 days later compared to healthy animals.

As a result of simulations performed for daily losses of milk (Table 2), it eventuates that every 100 heads of diseased animals depending on LSc brings daily losses of milk amounted from 32 kg (score 2) to 283 kg (score 4), as compared to healthy cows. It generates financial losses from $ 13.2 (score 2 of locomotion) to $ 116.95 (score 4) per day.

Conclusion

Lactation stage and locomotion score were the factors influencing the production and economic losses. The current study demonstrated that the locomotion score 4 in PP cows caused the highest decrease in the milk production ranging from 11% in the third lactation stage to 14% in the second period compared to healthy cows. We have also obtained a confirmation for the hypothesis that PP cows with fourth LSc approached the automatic milking system less often in the second lactation stage than healthy animals and gave less milk per single milking. PP cows with locomotion score 3 used a milking robot 18% more often in the third stage of lactation than in the first.

Losses due to reduced milk production generated by 100 lame cows amounted to 129 kg per day. In the financial dimension, these losses were amounted to PLN 193.50 which was giving $ 53.31. Daily milk production decline deepened with the score of progressive lameness and lactation stage, which had a direct impact on the value of financial losses.

Disclosure statement

No potential conflict of interest was reported by the authors.

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