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Assessment of dairy cow herd indices associated with different milking systems

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Abstract. The objective of the research was to find whether any differences exist between cattle herds operated by certain milking installations. The cattle herds were studied not only by herd size but also by certain data, like annual milk yield, age and number of lactations. Data collected on dairy farms that operate pipeline milking systems, milking parlours and automatic milking systems were analysed. These farms are situated in three Baltic States. The investigated Estonian dairy farms indicated a decreased tendency in the prevalence of disease cases for udder diseases with an increase in cow herd size. An index of cow production potential was proposed to compare different (including number of lactations) group of cows in dairy farms.

Key words: AMS, cow herd, dairy production, milking parlour, pipeline milking system.

INTRODUCTION

A dairy farm constitutes a complex system, in which many factors and relationships between the factors can be identified. Dairy cattle, technical equipment, biological material (e.g. forages and other necessary feed resources and water) as well as technological solutions, such as housing systems, determine the dairy production potential in particular farms. Each of these elements of the dairy farm production potential can encourage the development of detailed research.

Milking is one of the most important jobs on a dairy cattle farm, and it also can be the most tedious one, having to be done two or three times every day. Hence, many studies have been carried out with the intention to further increase milking efficiency in dairy farms. In practice technical parameters, functional facilities, productivity, labour intensity, energy consumption, the structure of some activities (e.g. milking, washing and idle time), cow herd management and others have been used as criteria to assess milking. Cooper & Parsons (1999) indicated the significance of economic aspects in a simulation model of automatic milking assessment. They concluded that dairy farmers, who are to switch from conventional milking to automatic milking, they should decide how to deal with the increase in milk yield, e.g. by reducing their herd size. Nitzan et al. (2006) developed models for simulating different type of milking parlours to predict milking parlor performance including herd size, number of milking stalls, labour quality, and cow characteristics. It was found that for a parlour with up to 14 milking stalls, a side-opening design provided greater capacity than parallel or rotary parlours. Wirtz et al. (2002) presented the problem of comparing AMS to conventional milking parlour, while Gygax et al. (2007) indicated that it would be valuable to compare functional aspects in certain automatic milking systems and milking parlours. Rotz et al. (2003) considered possible relationships between milking, farm size and milk production. Some connections between producer satisfaction, efficiency, and investment cost factors of different milking systems were investigated by Wagner et al. (2001).

Milking systems differ considerably in particular countries based on the type of agriculture applied. In Estonia, similar to the USA, farms often hold large herds of dairy cows and the milking process is performed by specialised personnel. This type of production is economically profitable only for large herds. In Estonia, as well as in Western Europe, there are also small farms, where most work is performed by the farmer and his family members. Currently there is an increase in number of farms with an average annual milk yield exceeding 10,000 kg of milk per cow. According to data obtained from the Estonian Livestock Performance Recording Ltd., at the end of 2016 there were 24 dairy farms with an annual milk yield of more than 10,000 kg milk per cow and in five farms even more than 11,000 kg. On one dairy farm the milk yield per cow was 12,239 kg at a herd size of 534.

In order to facilitate increased milk yield considerations regarding milking aspects such as milking system and/or farm equipment and personnel have to be included and related to the given production settings.

The objective of the current study was to explore differences between cattle herds operated by pipeline milking systems, milking parlours and automatic milking systems situated in three Baltic States. It was expected to find associations between herd characteristics and different milking systems that could be used to analyse milking efficiency. Identification of herds were evaluated by means of herd size, annual milk yield, age, number of lactations and health problems.

MATERIALS AND METHODS

To carry out detailed analyses, proper data were monitored and collected in dairy farms in Estonia, Latvia and Poland. The sampling strategy of data depended on availability of particular data in the investigated dairy farms.

Estonian data were collected from eight dairy cattle farms. The main criterion to select the farms for investigation was the type of used milking system. When compiling data, the number of milking stalls was also included in farms equipped with both AMS and milking parlour (Table 1). The farms differed in cow herd size. All farms in Estonia raised the Estonian Holstein breed. The herds were housed indoors throughout the year in a free-stall barn on six enterprises and on two enterprises in tie-stall barn.

Estonian research data – apart from information given in Table 1 – included cow performance and health data. The health data, i.e. udder diseases, feet diseases, fertility problems, accidents, metabolic problems and low productivity problems were included as outcome variables, while milking system and cow herd size there were explanatory variables in the statistical analysis to assess possible associations between cow health and herd size or milking system. Based on the numbers of each kind of health and productivity problems prevalence of disease cases of the given problems in individual dairy farms were calculated. The prevalence of disease cases was calculated as a relation of the number of health / productivity problems to average cow herd size, including observations for one year.

The two Latvian dairy farms differed as to milking systems. One farm was keeping a group of 145 cows and milking them with use of two AMS installations, while the second dairy farm was equipped with side by side milking parlour to handle 320 cows (Table 1).

Table 1. Data concerning dairy farms included in the investigation

Country	Milking system	Number of farms	Cow herd size	Description of milking system
Estonia	AMS	2	347, 380	6×1-stall AMS, 6×1-stall AMS
	Milking parlour	4	360, 505, 605, 617	2×7 hb, 2×10 p, 2×10 p, 2×10 p
	Pipeline	2	130, 170	
Latvia	AMS	1	145	2×1-stall AMS
	Milking parlour	1	320	2×10 sbs
Poland	AMS	1	140	2×1-stall AMS
	Pipeline	1	65	

Description: AMS – automatic milking system; hb – herringbone milking system; p – parallel milking system; sbs – side by side milking system.

The two Polish dairy farms were equipped with different milking systems, too. One of the farms was using two AMS to handle two independent groups of cows. The total herd size in the farm with automatic milking system was 140 cows. The second Polish farm was milking 65 cows using a pipeline milking system (Table 1). The farms raised Holstein Friesian breed. Apart from cow herd size, other data were compiled on Polish farms comprised by the study, i.e. milk yield, milk fat and protein content. These independent variables were used to calculate a proposed index of cow production potential for two farms. Cow production potential was only calculated for Polish farms. Since not all research data were accessible in each dairy farm and country, it was only possible to compare proper data and indices for dairy farms within each country, but not between the countries.

To calculate the index of cow production potential the following formula was proposed:

$$I_{cpp} = \frac{\sum_{1}^{n} Y_m \cdot p_f \cdot p_p}{100 \cdot n} \qquad (1)$$

where I_{cpp} – index of cow production potential; Y_m – milk yield per day (kg day^{-1}); p_f – percentage of milkfat content (%); p_p – percentage of protein content (%); n – number of analysed months (periods).

To find the I_{cpp} value for each cow, the data collected during one year were taken into account. The data concerning milk yield per day, percentage of milkfat and protein were compiled at a frequency of one day per month, according to general rules provided in Poland by the national system of dairy cows recording.

The index of cow production potential (I_{cpp}) was used to assess cows in two Polish dairy farms equipped with AMS and pipeline milking system. With the use of the index we compared two cow herds. Cows in the herds represented different lactation numbers on farms. The calculated index values for each cow were taken to show distribution of the index for cows with different lactation number in two considered herds.

Statistical analysis only for collected Estonian data was performed using the Statistic v.13 software. The descriptive statistical indicators, i.e. mean and standard deviation were determined for the assessed cows and cow herds. The comparison of data obtained in the dairy farms with three different milking systems (automatic milking system, milking parlour and pipeline milking system) was conducted using the ANOVA test. The significance level was $\alpha = 0.05$. A multiple range test for comparing means in the analysis of variance, i.e. Duncan test was used; homogeneous groups were identified. The data were also analyzed by analysis of variance with herd as a random effect and the annual milk yield per cow, and the prevalence of health problems as fixed effects. Linear regression was used to show relationship between herd size and some factors concerning cows.

RESULTS AND DISCUSSION

An analysis of data concerning cow herd size and milk yield for Estonian dairy farms equipped with various milking systems showed that the highest and lowest value of standard deviation (SD) concern farms, in which automatic milking system (AMS) was used (Table 2). There were only two Estonian farms with AMS included in the survey. Farms were equipped with the same number of six stalls (Table 1), while the difference between cow herd size was about 10%. For such data the SD amounted to ±23 cows. On the other hand the SD for annual milk yield per cow in farms with AMS amounted to ±1,843 kg cow^{-1} year^{-1}. Such SD value was ten times higher as compared to the relevant SD value for dairy farms equipped with a milking parlour (Table 2). Annual milk yield per cow in both Estonian farms with AMS was as following: 11,637 and 9,030 kg cow^{-1} year^{-1}. Such data suggest possible differences between dairy farms in terms of efficiency of AMS use and confirm other observations showing differences in efficiency of AMS use on the national level – between countries (Gaworski, 2016).

Considering milk fat content recorded in the investigated Estonian dairy farms the following data were found for farms with AMS, milking parlour and pipeline milking system (mean ± SD): 3.99 ± 0.08%, 3.91 ± 0.21% and 4.26 ± 0.33%, respectively. The milk protein content for the mentioned milking systems amounted to (mean ± SD): 3.35 ± 0.04%, 3.32 ± 0.04% and 3.37 ± 0.04%, respectively.

A comparison of data – according to results of analysis of variance (ANOVA) – obtained from Estonian dairy farms (Table 2) showed significant differences ($p < 0.05$) in herd size of dairy cows operated by distinguished milking systems. But results of the analysis of variance did not point to significant differences in mean values ($p > 0.05$) for annual milk yield per cow based on the different milking systems.

The significant differences in herd size of dairy cows kept in the farms comprised by the study confirm that general rules concerning selection of milking system to number of cows were fulfilled. Generally, an increase in cow herd size is associated by selection of milking system characterized by higher and higher capacity, i.e. amount of milk collected per hour. Proper milking systems in dairy farms can be a source of satisfaction, efficiency, and optimized investment costs that are beneficial for producer (Wagner et al., 2001). Thanks to criteria for optimization (Kic, 2015) it is possible to equip farms with milking installations that support effective dairy production systems.

Results of the variance analysis (Table 2) point to substantial differences in mean values ($p < 0.05$) for prevalence of udder diseases between the compared milking systems. Thus, the results of the present study emphasize the importance of the milking system for variables representing health of dairy cow herd. Examples of in-depth investigations (Rasmussen et al., 2001) show that the problem of mastitis and other diseases in dairy farms can be a field of individual assessment of each milking system, including AMS.

The problem of udder diseases is connected with milking (Svennersten-Sjauna et al., 2000). However, the data collected in Estonian dairy farms included also other health problems. The analysis of variance showed significant differences – concerning some other health problems, i.e. feet diseases, fertility and metabolic problems – between farms with considered milking systems (Table 2).

Table 2. Analysis of variance for cow and cow herds, including prevalence – mean ± SD – for compared cow herds operated by different milking systems within recorded data for one year

Farms with milking system	Herd Size	Milk yield	Udder diseases	Feet diseases	Fertility problems	Accidents	Metabolic problems	Low product
	Heads	kg cow^{-1} year^{-1}	%	%	%	%	%	%
AMS	364^{a,b}	10,334	6.05^{a}	4.25^{a}	6.22^{a}	1.80	2.74^{a,b}	1.79
	±23	±1,843	±0.00	±0.31	±0.98	±0.31	±0.21	±0.08
MP	522^{b}	10,598	4.61^{a}	3.15^{a}	3.92^{a}	2.00	1.88^{a}	0.77
	±119	±178	±1.45	±0.78	±0.81	±0.80	±0.63	±0.33
PPL	150^{a}	8,307	13.87^{b}	8.62^{b}	11.83^{b}	3.69	4.07^{b}	1.74
	±28	±284	±2.14	±3.04	±1.76	±0.22	±0.77	±0.80
p-value	0.0158	0.0609	0.0020	0.0216	0.0012	0.0513	0.0233	0.0620

AMS – automatic milking system; MP – milking parlour system; PPL – pipeline milking system; $^{a,\,b}$ – denoted homogenous groups; the different letters a and b refer to the significance of difference between the values in column at the level of at least 95%.

Analysis of variance with herd as a random effect showed significant difference ($p < 0.05$) in mean values for udder diseases, metabolic diseases, and fertility problems for Estonian dairy farms.

Data concerning annual milk yield per cow and health problems, i.e. prevalence of udder diseases in Estonian dairy farms, were correlated with cow herd size in these farms (Figs 1, 2). The annual milk yield per cow is characterised by increase trend, while prevalence of udder diseases is characterised by decrease trend when the farms with higher and higher cow herd size are considered. The results of the linear models show a high r value for the analysed relationship between prevalence of udder diseases and cow herd size (r = 0.93), while r value for the relationship between annual milk yield per cow and cow herd size amounted to 0.65. The high (r) value indicates that the model for the prevalence of udder diseases well fit the data included in the analysis. On the other hand because of relatively small sample size extrapolation in general should be made with caution and it would be valuable to consider data comprising more cow herds to confirm observed relationship between the prevalence of udder diseases and cow herd size.

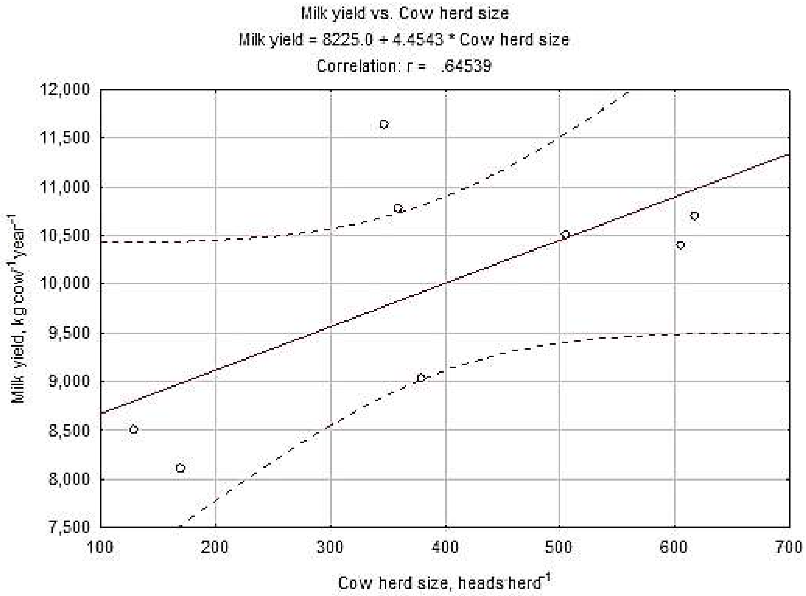

Figure 1. Relationship between cow herd size and annual milk yield per cow.

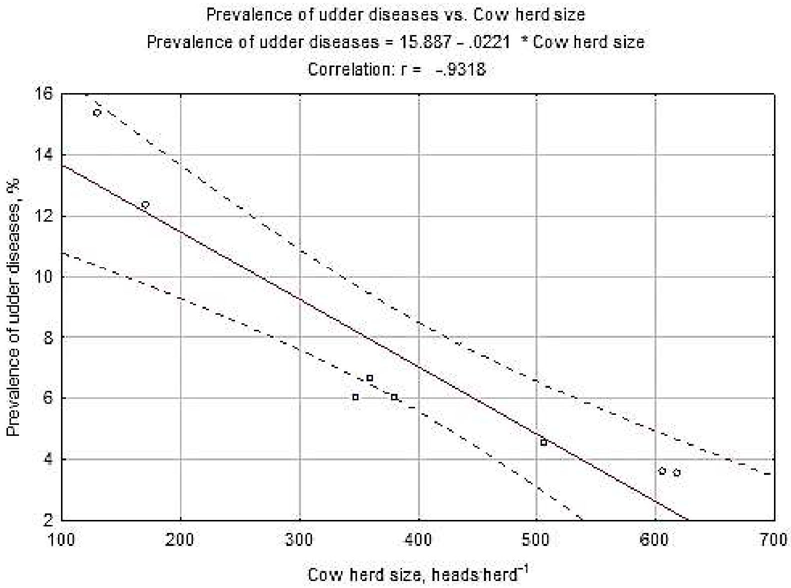

Figure 2. Relationship between cow herd size and prevalence of udder diseases.

The health problems included in the executed investigations constitute only a smaller part of health aspects considered in the specialist literature. Hillerton et al. (2004) emphasized the role of further elements in the cow health assessment, including such features as locomotion, body condition (including teat conditions), fertility, cell count and generally udder health. King et al. (2016) investigated lameness prevalence as well as herd-level housing and management to find any associations with productivity and cow behaviour in herds with automated milking systems. The prevalence of severe lameness was positively associated with stocking density, while doubling the prevalence of severe lameness (from 2.5 to 5%) was associated with decrease in milk production of 0.7 kg per cow per day. Cook & Nordlund (2009) investigated influence of the environment on claw health and herd lameness dynamics. The environment included different type of floor, bedding material and stall design in lying area as a main criteria to compare dairy farms. For such data there was possible to show effect of some factors representing direct contact with animals on health problems. In our research approach the health problems were considered for different cow herd size, which can be included as an indirect factor in the cow health analyses. Some aspects of cow health problems recognized in dairy herds with tiestall, freestall, and automated milking systems were investigated by Higginson Cutler et al. (2017). It was concluded that producers underestimate lameness prevalence, which highlights that lameness detection continues to be difficult in all housing systems, including especially herds with tiestall system.

The most interesting results were obtained by the comparison of the number of lactations in the two Latvian dairy farms. In the farm equipped with automatic milking system the number of lactations per cow was 4.19 ± 0.38, while number of lactations per cow in the farm with side by side milking parlour amounted to 3.15 ± 0.20. Such results can be inspiration to develop discussion on the problem of cow longevity. Improved longevity can show effect on an increased productivity of the herd, because replacement, reproduction and veterinary costs are lowered, while mean milk production of the herd is increased (Olechnowicz et al., 2017). Rushen & de Passillé (2013) indicated that elimination of the main causes of involuntary culling significantly improves cow longevity and increases profits of the farm.

Results of Latvian dairy farms comparison indicate differences between some data describing cows in the farms equipped with AMS and milking parlour. When compared AMS with typical milking parlour it is possible to notice that because cow do seek more milkings when they can do it voluntarily in the AMS systems so it might be expected, that farms with conventional milking systems could increase their number of daily milkings. Considering milking data of 34 single automatic milking system (AMS) units on 29 Galician dairy farms Castro et al. (2012) found that the daily milking throughput could be maximized at 2.4 to 2.6 milkings per cow. The same authors indicated that the efficiency of the AMS use can be recognized by percentage of milking time, i.e. the percentage of hours the AMS is actually milking per day. Milking capacity expressed by the number of cows that the automatic milking system is able to milk, can be determined by the individual performance of the cow and the settings of the system parameters (Komiya et al., 2002). To evaluate automatic milking system and milk yield Bach & Busto (2005) measured milking interval regularity and teat cup attachment failures; uneven frequency (weekly coefficient of variation of milking intervals > 27%) decreased daily milk yield.

Another criteria to compare dairy farms with AMS and conventional milking parlour there is technical efficiency. Steeneveld et al. (2012) analysed actual farm accounting data for 400 Dutch dairy farms. They found that farms with AMS had significantly higher capital costs (12.71 euro per 100 kg of milk) than farms with conventional milking system (10.10 euro per 100 kg of milk). Another hand, total labour costs and net outputs were not significantly different between farms with AMS and conventional milking system.

An analysis of data compiled in two Polish dairy farms allowed the identification of the percentage of cows representing the different lactation numbers in the farms. A comparison of the farm equipped with pipeline milking system and a farm with AMS shows that a considerable part of the given herds include young animals, i.e. cows in first and second lactation in this case study example (Fig. 3). It can be interesting that total percentage of cows in first, second and third lactation is nearly the same (about 89%) in each of two farms. Results of the observation can inspire further analyses of more herds to confirm or negate these trends concerning the distribution of age groups by taking lactation numbers into account.

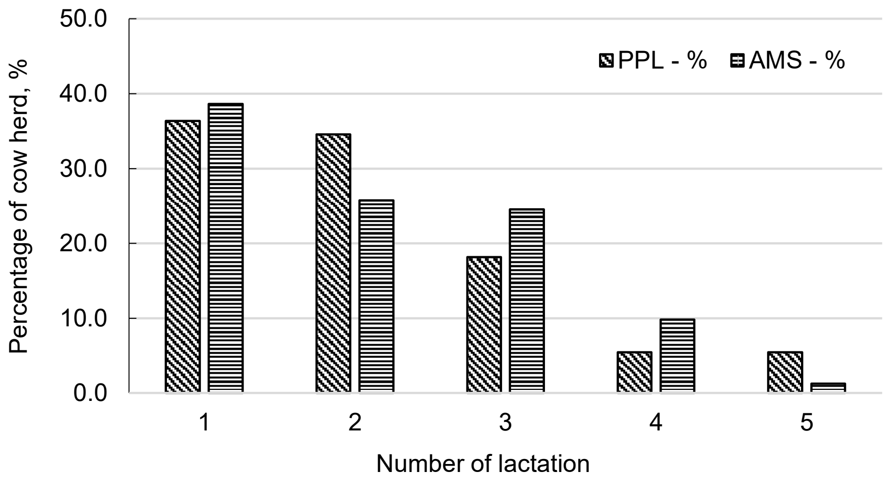

Figure 3. Percentage of cows in different lactation for two Polish farms, i.e. equipped with pipeline milking system (PPL) and automatic milking system (AMS).

Changes in the index of cow production potential were presented for an independent variable, i.e. the number of lactations, including cows handled by pipeline milking system (Fig. 4) and automatic milking system (Fig. 5).

Based on the shape of the two curves presenting changes of the index of cow production potential (I_{cpp}) for cows handled by pipeline milking system and automatic milking system, respectively, differences in the age distribution of cows are seen. The curve for the pipeline milking system herd shows an increasing tendency for successive lactation groups (Fig. 4), while the curve for the automatic milking system herd indicates maximum value of the I_{cpp} index for fourth lactation group (Fig. 5).

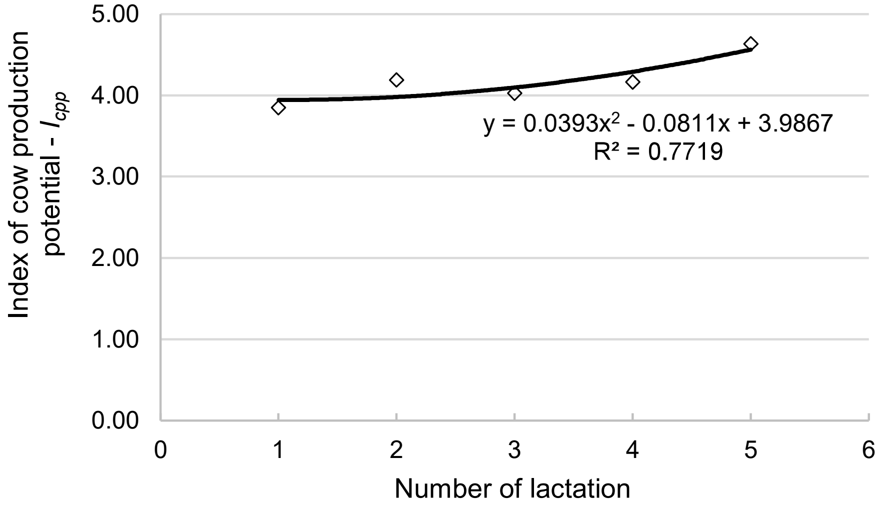

Figure 4. Changes in index of cow production potential (I_{cpp}) for cows in different lactation in farm equipped with pipeline milking system.

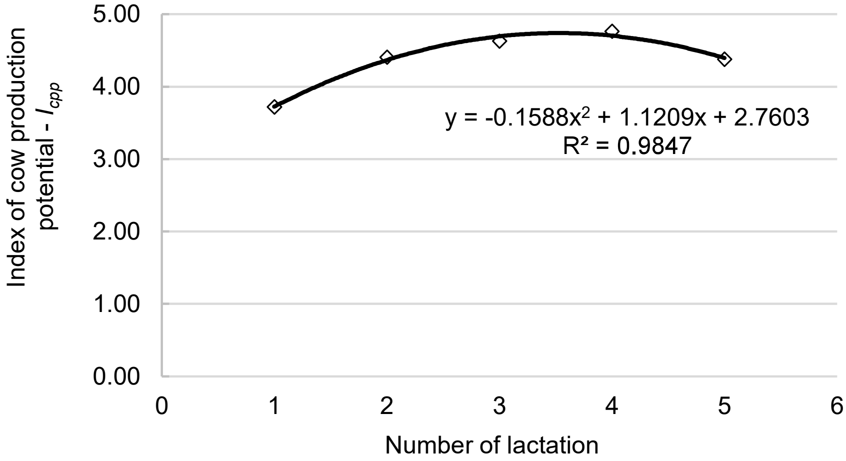

Figure 5. Changes in index of cow production potential (I_{cpp}) for cows in different lactation in farm equipped with automatic milking system.

Including data collected in the two Polish dairy farms and results of calculation suggests that that highest values of the index of cow production potential (Figs 4–5) are associated with the lowest values of the percentage of cows in the analysed herds, i.e. cows in fourth and fifth lactations (Fig. 3). Such observation for two investigated farms show that animals with most valuable production indices constitute the lowest percentage in the cow herds handled by pipeline and automatic milking systems.

Milking systems, cows and cow herds are subjects included in the process of dairy production improvement, where one of the most important aims is the achievement of higher and higher efficiency of dairy production. Dairy production efficiency can be expressed by different indices, e.g. concerning milking systems and details concerning milking performance (Davis & Reinemann, 2002; Bach & Busto, 2005) and quality

(Klungel et al., 2000; Rasmussen, 2002) to show changes in milk quality parameters before and after introduction of interventions in dairy farms like automatic milking systems. Factors that affect the capacity of the automatic milking system (Priekulis & Laurs, 2012), including different conditions of dairy production development and effective AMS use (Gaworski et al., 2013), constitute a key element in the execution of studies concerning relationships between technical and biological potential in dairy production (Gaworski & Leola, 2014).

CONCLUSIONS

Results of the undertaken study confirmed that general rules concerning selection of milking system to number of cows were fulfilled in the investigated Estonian dairy farms. Generally, the increase in cow herd size was associated with selection of milking system characterized by higher and higher annual milk yield per cow.

The cases investigated in the Estonian dairy farms showed a decreased tendency in prevalence of udder diseases with increase in cow herd size. Such results are limited to the present study and cannot be extrapolated to the dairy population. In the perspective approach it could prove to be valuable to continue analyses related to cow health problems arising from different milking systems.

The Latvian cases showed possible differences as to the number of lactations per cow in farms with AMS and milking parlour.

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