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DAIRY COW LONGEVITY IN VOLUNTARY MILKING SYSTEM

Lāsma Cielava[1], Daina Jonkus[1], Sandija Zeverte-Rivza[2], Baiba Rivza[2]

[1] Latvia University of Life Sciences and Technologies, Faculty of Agriculture, [2] Latvia University of Life Sciences and Technologies , Faculty of Economics and Social Development

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Abstract

The increase of dairy production leads to the higher demand for the automation of some processes in farms. The large benefits for farmers usually does not give the same results for cow welfare and leaves significant mark on the cow potential lifespan. The aim of our study was to determine until what extent different factors affect the longevity traits of cows in voluntary milking system. In study were included 114 dairy cows that were included in voluntary milking system (VMS) group from year 2013 to 2018. The data about cows were collected from Latvian "Agriculture Data Center". Cows were distributed in the 3 – 4 different groups depending on their milk productivity, milk quality, udder depth linear evaluation score and stature in the first lactation. The average lifespan of analyzed cows were 1824.2±52.05, when were obtained 30317.9±1280.25 kg milk that leads to 16.1±0.35 kg milk per one life day. Analysis of factors showed tendency that the significantly ($p<0.05$) longest lifespan and the lowest lifetime milk productivity were observed in group with lowest productivity in the first lactation (accordingly 2257.2±196.10 days with 37414.7±4499.70 kg milk). The somatic cell count (SCC) in milk showed similar tendency that highest longevity trait values were obtained in groups with the lowest SCC (accordingly 34170.7±2991.62 kg and 17.1±0.85 kg milk). The type trait analysis showed the tendency to decrease with the increase of type trait score. In the udder depth group the longest lifespan (2014.2±240.48 days) were observed form cows with udder depth evaluation score <5 points.

Keywords: udder conformation, lifespan, milk productivity.
JEL Codes: Q00, Q01, Q10.

Introduction

With the intensification of dairy farming, there is tendency not only to increase cow milk productivity, but also to increase the demands for dairy cow welfare. In farms with small number of cows, it is easier to pay attention to the needs of individual cow, but larger holdings often have to make a hard choice between their profitability and the welfare of their animals (Jacobs and Siegford, 2012). One of the solutions for farmers is the use of modern technologies that can give insight not only about the changes of milk productivity, but also can evaluate microclimate and welfare conditions in the barn. The voluntary (automated) milking system (VMS) almost completely excludes the human factor from cows' life but, by doing that it does not eliminate the possibility to collect data about individual animals (Bergea et al., 2016).

One of main problems with VMS is that the cows, that are included in the VMS group needs to meet certain standards for their milk productivity, udder conformation, stature and other traits (Siewert et al., 2018). With the increase of age there is tendency for milk productivity to increase, in the meantime the milk and udder quality rapidly decreases (Castro et al.,2018) thus decreasing the possibility for cow to remain in VMS group. As there are small chance to reintroduce cow to milking parlor or other milking solutions, usually exclusion from VMS means culling from herd (Olechnowicz et al., 2016).

There are many different factors (internal and environmental) that can reduce the potential lifespan of cows in farm. The most common reasons for the cow exclusion from VMS is low milk productivity (Cielava et al., 2017), poor milk quality (Milostiviy et al., 2017) and udders inadequacy for the automatic milking (Kern et al., 2015). The proper selection after the most useful traits (for VMS) can improve not only cow lifespan, but also the quality of obtained milk (De Vries, 2017).

As the rearing process of qualitative dairy heifers is very expensive and the adaptation process to VMS is long, it is important to maximally extend the lifespan of each animal located in automatic milking group. By doing that it would be possible not only increase the potential milk productivity and longevity, but also increase the total profitability of each cow in group (Berry, 2015).

The aim of our study was to determine until what extent different factors affect the longevity traits of cows in voluntary milking system.

Materials and methods

The study was carried out in Latvia University of Life Sciences and Technologies (LLU) research and study farm "Vecauce". In farm there are 2 different milking systems – Voluntary milking system (VMS) (DeLaval) and milking parlor (herringbone DeLaval). The cows in the VMS are included from first calving up until the culling. In some cases cows that were excluded from VMS were tried to adapt for milking in parlor.

Cows in VMS are fed with the partially mixed ration and they have unlimited access to fodder stations where they can receive preprogramed amount of fodder. The fodder stations are located in two places - the waiting area before the milking unit and also in the milking robot. The amount of fodder, given to cows, is calculated by the system.

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In the VMS group in each given time are included 100 Holstein Black and White (HBW) dairy cows. For study purposes we used Data about 114 HBW dairy cows that were included in VMS group from year 2013 to 2018. From Latvian "Agriculture Data Centre" we collected data about cow:

- lifespan (birth date and culling date);
- milk productivity (in the first standard lactation and in later full lactations);
- milk quality in the first lactation (somatic cell count);
- body conformation trait – udder depth and stature - linear evaluation results (in the beginning of first lactation).

From the productivity data were calculated lifetime milk productivity (LMP) and later by formula (1) were calculated average life day milk productivity:

$$LDMP = \frac{LMP, kg}{Lifespan, days}, kg\ milk\ per\ day \quad (1)$$

To determine the effect of different factors on VMS cow longevity traits, analyzed factors were included in the model (2):

$$Y_{ijkl} = \mu + P_i + Q_j + U_k + S_l + e_{ijkl}, \quad (2)$$

Were:

Y_{ijkl} – observations of variable of interest;
μ – underlying constant;
P_i – fixed factor milk productivity;
Q_j – fixed factor milk quality;
U_k – fixed factor udder deoth evaluation score;
S_l – fixed factor cow stature;
e_{ijkl} – the random residual.

To determine the effect of milk productivity, milk quality and stature in the first lactation on the lifespan of dairy cows in VMS group, we distributed cows in four different groups. The udder depth linear evaluation score was distributed in three groups where the middle group were chosen as the optimal evaluation score. (Table 1).

Table 1. The number of cows in each study group and average milk productivity, quality and analyzed stature traits in each group

Factor	Average per group	Number of cows in group
Milk Yield in the first lactation, kg		
<8000	6728.8±353.41	20
8000 - 10000	9111.3±101.21	29
10000 - 12000	11350.9±117.62	42
>12000	15708.7±334.59	23
Milk quality in the first lactation, somatic cell count, thousands in 1mL^{-1}		
<30	20.9±0.87	22
30 - 100	47.5±1.91	42
100 - 200	144.5±6.71	20
>200	579.8±148.5	23
Udder depth linear evaluation score at the beginning of first lactation, points		
<5	3.8±0.04	14
5	5.0±0.00	85
>5	6.3±0.05	15
Stature at the beginning of first lactation, cm		
135 - 141	137.8±0.86	7
141 - 145	143.8±0.17	39
146 - 150	147.6±0.20	54
151 - 155	152.4±0.37	14

The factor impact on cow longevity and productivity traits were determined by analysis of variance. Pairwise comparisons between traits occurred by using Bonferroni test ($p<0.05$). The analysis of Survival were conducted with Kaplan-Meier survival curves.

Data in tables are represented as mean value ± standard error. The factors significant effect on lifespan and lifetime milk productivity traits were denoted with different superscripted alphabet letters (^{ABC} etc.). The mathematical processing of data was performed with IBM SPSS 20.0 program package.

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Results

The one of main factors that leads to dairy cow premature culling not only in the voluntary milking system (VMS), but also in the conventional is cow milk productivity. Normally cows are included in VMS group after first calving thereby decreasing the stress connected with the adaptation to new housing and milking system.

In LLU Study and research farm "Vecauce" VMS the average milk yield in the first lactation was 11666.1±344.51 kg, that was significantly higher than in the second lactation ($p<0.05$). From analyzed 114 dairy cows the third lactation reached only 22% (25 animals), that indicates either on hard adaptation or space for improvement in the selection process for VMS (Table 2).

Table 2. The milk productivity and quality traits of cow milk in first and subsequent lactations

Trait	Lactation		
	1 (N=114)	2 (N=61)	3 (N=25)
MY	11666.1±344.51^{A}	9867.6±344.33^{B}	10174.7±888.49^{AB}
MF	3.86±0.04^{A}	3.98±0.05^{B}	3.89±0.11^{A}
MP	3.36±0.02	3.34±0.03	3.35±0.05
SCC	83.7±13.63^{A}	92.6±14.57^{AB}	103.1±20.89^{B}

MY – milk yield, kg; MF – milk fat content, %, MP – milk protein content, %; SCC – somatic cell count, thous. 1 mL^{-1}
^{ABC} – different subscriptions denotes significant differences between lactations ($p<0.05$)

The somatic cell count (SCC) had the tendency to increase with the age of cows (accordingly 83.7±13.63 thousands in 1 mL^{-1} milk in the first lactation and 103.1±20.89 thousands in 1mL-1 milk in the third lactation). The milk composition traits did not fluctuate in between lactations.

In studied group cows characterized with 1824.2±52.05 days long lifespan in which were obtained 30317.9±1280.25 kg milk. The average life day milk productivity was 16.1±0.35 kg (Table 3). All longevity traits characterized with large amplitude, the lowest life day milk productivity was almost 7 times lower than the highest one. The large amplitude is explainable by different culling reasons in different stages of lactation (Fouz et al., 2014).

Table 3. The lifespan and lifetime milk productivity traits of cows in voluntary milking system

Trait	$\bar{x} \pm S_{\bar{x}}$	Min	Max	V, %
LS	1824.2±52.05	754	4211	30
LP	30317.9±1280.25	2920	81293	44
LDP	16.1±0.35	3.9	26.8	23

LS – lifespan, days; LP – lifetime milk productivity, kg; LDP – life day milk productivity, kg.

The milk productivity in the first lactation can serve as indicator for cows' future potential milk productivity, but also, low level of productivity can increase the possibility that cow will be culled from herd after first lactation. (Janus and Borkowska, 2012). As in the VMS group are included high yielding cows, in the low productivity group were included ones with milk productivity <8000 per lactation (Table 4).

Table 4. The effect of milk productivity in the first lactation on dairy cow lifespan and lifetime productive performance

Milk Yield	Longevity traits		
	LS	LP	LDP
<8000	2257.2±196.10^{A}	37414.7±4499.70^{A}	15.5±1.15^{A}
8000 - 10000	1776.3±65.25^{B}	28236.4±1850.79^{B}	15.5±0.60^{A}
10000 - 12000	1767.7±78.84^{B}	29941.3±2070.16^{B}	16.5±0.56^{B}
>12000	1549.0±82.92^{C}	28076.2±2379.85^{B}	16.5±0.68^{B}

LS – lifespan, days; LP – lifetime milk productivity, kg; LDP – life day milk productivity, kg.
^{ABC} – different subscriptions denotes significant differences between milk productivity groups ($p<0.05$)

In between the milk productivity group there are drawn strong tendency to decrease lifespan with the increase of milk productivity in the first lactation. The difference between the low and high yielding cow groups (accordingly <8000 kg and >12000kg milk per first lactation) was 708 days (approximately 2 years). The same tendency were observed in the lifetime productivity group – cows with higher milk productivity in the first lactation had significantly lower lifetime milk productivity, but in the same time the highest life day milk productivity (accordingly 28076.2±2379.85 and 16.5±0.68 kg milk). The tendency could be explained with the fact that high milk yield usually comes with different udder problems and significantly higher somatic cell count (SCC) in latter lactations (Dorynek et al., 2006).

Proceedings
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The milk quality was characterized by the SCC in milk in the first lactation. The extensive amount of SCC in milk (>200 thousands in 1 mL^{-1}) often leads to udder inflammation and mastitis (Hovinem and Pyorala, 2011). The treatment process is very expensive and therefore cows with increased SCC in first lactation are culled sooner (De Vries, 2017). In our study were found out that the significantly longest lifespan were in cow group with the SCC <30 thousands in 1 mL-1, and in this group were observed the highest life and life day milk productivity (accordingly 34170.7±2991.62 and 17.1±0.85 kg). (Table 5). With the increase of SCC in the first lactation, the average lifespan, lifetime milk productivity and life day milk productivity significantly decreased and in the last SCC group (>200 thousands in 1 mL^{-1} milk) the average life day milk productivity were 2.6 kg lower than in the first group.

Table 5. The relationship between milk quality in first lactation and cow lifetime performance

SCC	Longevity traits		
	LS	LP	LDP
<30	1926.9±94.09^{A}	34170.7±2991.62^{A}	17.1±0.85^{A}
30 - 100	1780.8±68.29^{B}	29015.0±1624.86^{B}	15.8±0.45^{B}
100 - 200	1940.8±164.05^{A}	32569.2±3589.80^{AB}	16.4±0.86^{AB}
>200	1625.3±143.39^{C}	25156.8±3655.17^{C}	14.5±1.58^{C}

SCC – Somatic cell count, thousands in 1 mL^{-1} milk; LS – lifespan, days; LP – lifetime milk productivity, kg; LDP – life day milk productivity, kg.
^{ABC} – different subscriptions denotes significant differences between SCC groups ($p<0.05$)

The SCC in milk can be determined by series of different factors. With the increase of cow age, one of those factors can be decrease of the quality of udder (Cielava et al., 2016). In our study were observed tendency that cows in the first lactation characterized with the udder with close to ideal proportions and maximum close to optimal linear evaluation scores, but later in the third lactation in each analyzed group, udder depth linear evaluation score indicated on the visible aging processes of different body parts. (Table 6). That is explainable with the strong selection process for cows to be included in the VMS group.

Table 6. The average lifespan and lifetime productivity traits depending on udder linear evaluation score in first lactation

UD evaluation score		Longevity traits		
1st lactation	3rd lactation	LS	LP	LDP
<5	3	2014.2±240.48^{A}	35444.3±7164.93^{A}	16.7±1.57^{A}
5	3.8	1823.5±56.75^{B}	30302.61379.03^{B}	16.1±0.36^{B}
>5	3.9	1686.9±144.78^{C}	27065.1±3485.94^{C}	15.3±1.54^{C}

UD – Udder depth, points; LS – lifespan, days; LP – lifetime milk productivity, kg; LDP – life day milk productivity, kg.
^{ABC} – different subscriptions denotes significant differences between udder evaluation score groups ($p<0.05$)

The udder depth as a trait shows significant impact on the analyzed longevity traits. The significantly longest lifespan, highest lifetime and life day milk productivity were obtained from cows with the udder depth evaluation score in the beginning of first lactation <5 points. In the study about the relationships between conformation traits and cow longevity in Poland (Morek-Kopec and Zarnecki, 2012) showed similar tendencies for cows with lower udder depth evaluation score characterizes with longer functional and true lifespan.

The overly large stature of Holstein Black and White (HBW) breed dairy cows is one of main reasons for poor health of legs and hooves (Kern et al., 2014). In our study results showed that the significantly longest ($p<0.05$) lifespan was in cow group with stature smaller than 141 cm, in this group included cows had also the highest lifetime milk productivity and milk productivity per one life day (Table 7).

Table 7. The changes of analyzed lifespan traits depending on the stature of cows in the first lactation

Stature, cm	Longevity traits		
	LS	LP	LDP
135 - 141	2333.6±216.82^{A}	43480.2±8146.66^{A}	18.1±2.18^{A}
141 - 145	1874.3±64.22^{B}	31694.8±1958.82^{B}	16.3±0.57^{B}
146 - 150	1788.4±90.21^{C}	29156.5±1999.1^{C}	15.7±0.53^{C}
151 - 155	1640.8±88.08^{D}	26261.3±1935.75^{D}	15.9±0.69^{C}

LS – lifespan, days; LP – lifetime milk productivity, kg; LDP – life day milk productivity, kg.
^{ABCD} – different subscriptions denotes significant differences between cow stature groups ($p<0.05$)

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In VMS it is very important that all included cows are similar for their body conformation. The cows with high stature (>146 cm) showed the worst results not only in lifespan, but also in the milk productivity per life and per life day. The life day milk productivity shows tendency to decrease in-between each stature groups, but in the fourth group (>151 cm) it showed small increase.

To evaluate the effect of different factors, in the study we used Kaplan-Meier survival analysis (Fig.1). The analysis of milk productivity in first lactation effect on dairy cow lifespan (Fig.1 (a)) showed tendency that cows in the first, lowest productivity group had tendency to cull the majority of cows later than it was in the other groups - the 60% of cows, included in first group lived past 2100 day border.

The SCC in the first lactation had similar tendency (Fig.1 (b)) where the largest proportion of cows with the lowest amount of SCC in milk lived past 2000 days. The results showed that the longest lifespan and life productivity traits higher were for cows in the first group (SCC<30 thousands in 1 mL^{-1} milk), but the survival analysis shows that the cows with longest lifespan in first lactation hat 30-100 thousands SCC in 1 mL^{-1} milk (approximately 20% of cows in this group lived past 4000 days).

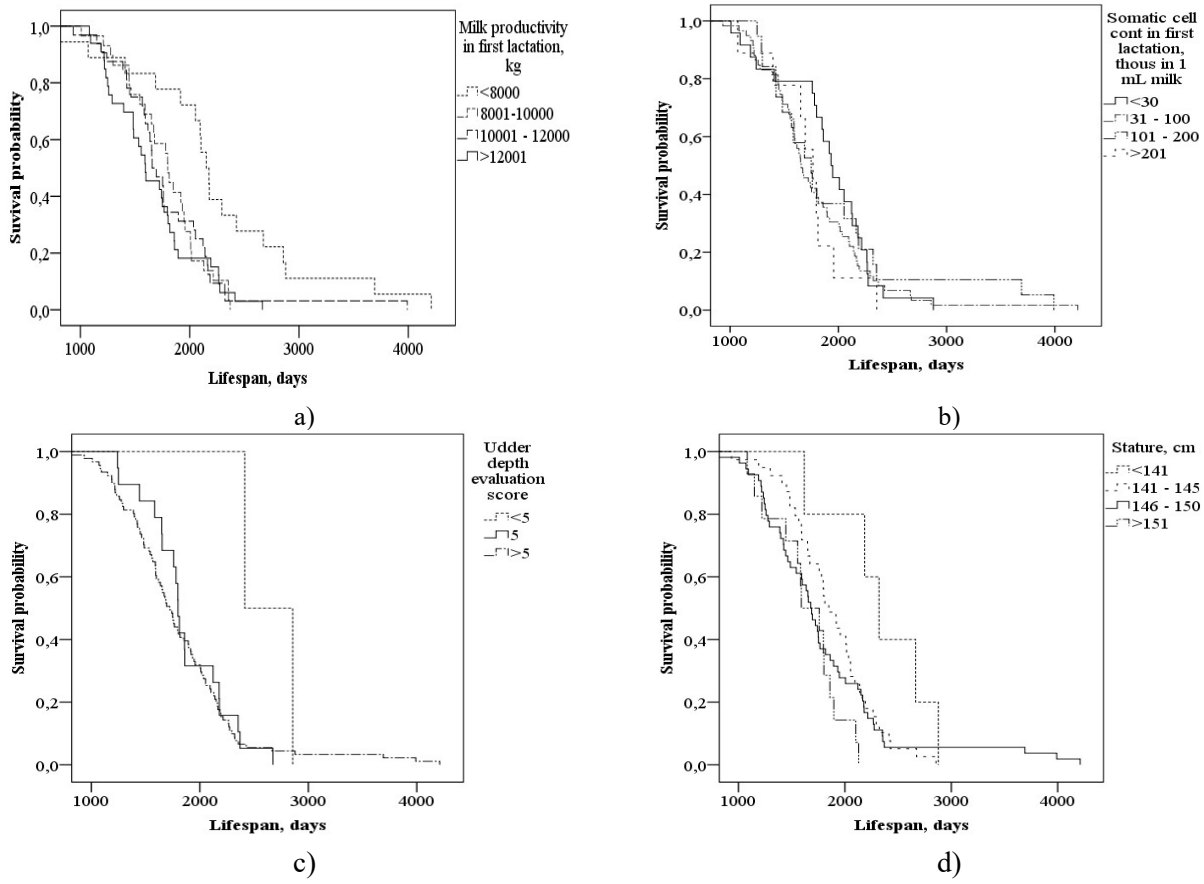

Figure 1. The survival probability of VMS cows depending on different factors – a) – milk productivity in first lactation; b) – somatic cell count in first lactation; c) – udder depth linear evaluation score in the first lactation; d) – the stature of cows in first lactation.

The lifespan of different cows depending on the stature of dairy cows in the first lactation showed similar tendencies like the SCC analysis. As the highest values of analyzed longevity traits were observed in the cow group with the smallest (by stature) cows, in the survival analysis results showed that cows with the longest lifespan was included in the third group with cow stature 146-150 cm. Approximately 10% of cows included in this group lived past 3750 days.

Conclusions

The analyzed factors showed significant impact ($p<0.05$) on the cow lifespan, lifetime milk productivity and life day milk productivity. The cows with the highest milk productivity in the first lactation (>12000 kg) characterized with significantly shorter lifespan (1549.0±82.92 days), but in the meantime showed the highest life day milk productivity results (16.5±0.68 kg). The cows with SCC <30 thous. In 1mL^{-1} characterized with one of the longest lifespans and the highest lifetime and life day milk productivity (accordingly 34170.7±2991.62 kg and 17.1±0.85 kg per day). In the farms, the analysis of factors affecting the milk productivity and quality in first and subsequent lactations, together with the improvement of the selection process for VMS can lead to prolonged lifespan of cows.

Proceedings
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Data about the author:

Lāsma Cielava, Mg.agr. Guest lecturer (Animal Science); Dairy production, dairy longevity, dairy cow breeding; Latvia University of Life Sciences and Technologies, Institute of Agrobiotechnologies, researcher; Liela iela 2 Jelgava, Latvija, LV-300; lasma.cielava@llu.lv

Daina Jonkus, Dr. agr. Professor (Animal Science); Animal breeding, genetics, dairy production**;** Latvia University of Life Sciences and Technologies, Institute of Agrobiotechnologies, head of institute; Liela iela 2 Jelgava, Latvija, LV-3001; daina.jonkus@llu.lv