

Relation between first lactation milk yield and functional traits in dairy cows

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Abstract. The aim of the study was to analyze the relationship between first lactation milk yield (FLMY) and age at first calving (AFC), longevity and productive life in dairy cows. The study covered 944 Holstein cows housed in 5 dairy cattle farms in Bulgaria. All cows from the five farms culled in the period 2012–2018 with FLMY data were included. The average AFC for all culled cows included in the study was relatively high for the Holstein-Friesian breed - 29.75 months. The average FLMY of the herds included in the study was 7,660.94 kg with significant herd variation from 5,899.09 kg to 8,646.0 kg. Significant effect of the herd ($P < 0.001$), AFC and the associated effect of the herd and AFC ($P < 0.05$) on the average FLMY were found. The highest FLMY was reported in primiparous with AFC of 28–30 months - 7,860.8 kg, and the lowest in those with $\text{AFC} \leq 24$ months - 7322.8 kg. In the herd with the lowest average FLMY - 5,899.09 kg 27.5% of the heifers had calved at age over 34 months. A statistically significant effect of AFC ($P < 0.001$) was found on longevity, whereas the productive life was significantly influenced by FLMY ($P < 0.05$). A tendency for higher longevity for cows with higher AFC of 34–37 months and over 37 months – 5.9 and 5.8 years, respectively was observed. The lowest were the longevity values for cows calved at age up to 24 months - 4.9 years. The cows with the lowest average FLMY (up to 4,000 kg) had the shortest productive. Both very low and high AFC were associated with lower first lactation cow productivity and shorter productive life. The losses for farmers were greater when keeping a high AFC in heifers, which increases the cost for housing them, and the lower productivity and longer productive life reduce the probability.

Key words: milk performance, primiparous, age at first calving, longevity, productive life.

INTRODUCTION

Basic functional traits such as age at first calving (AFC), longevity and productive life affect genetic progress and economic indicators in dairy cows (Teke & Murat, 2013; Penev et al., 2014; Caetano et al., 2017). The AFC is particularly important since it affects fertility, milk performance and duration of productive life and hence the economic return in the dairy sector (Cooke et al., 2013; Zavadilová & Štípková, 2013; Sawa et al., 2018; Fodor et al., 2019). Heifer rearing equals 15 to 20% of total milk production costs, thus representing the second largest share of costs after feed costs at

farms (Tozer & Heinrichs, 2001). The goal of dairy farm owners is to minimize costs and maximize future income from heifers, but contemporary goals also include considerations for ecological impacts and animal welfare (Heinrichs et al., 2017).

There are many reasons for dairy farmers to want animals that are used longer. Although the most important consideration is economic benefits, achieving a long life in the herd is still a great challenge. Although the natural life of a cow may exceed 15–20 years, cows in modern farms are culled on average age of 4.5–6.6 years (Cielava et al., 2017). In Belgium, it was found that less than one third of the cows reach the fourth lactation (Gengler et al., 2005). Other authors in other countries report relatively short productive life of dairy cows. The average productive life of a cow in Sweden is 2 to 2.5 lactations (Carlén & Eriksson, 2013), which means that a cow that has its first calf at the age of 30 months may not be able to pay back its rearing cost before culling. There are several studies on the relationship between cow use duration and survival and the milk yield (Pool et al., 2003; Ajili et al., 2007; M'hamdi et al., 2010; Grayaa et al., 2019). An important indicator of selection and culling in primiparous is their first lactation milk yield (FLMY). It is largely influenced by the AFC, which in turn is a factor related to the duration of rearing. Clarifying these dependencies, which are specific for the various herds, is important for the overall strategy of dairy farms. The aim of the study was to analyze the relationship between FLMY and AFC, longevity and productive life in dairy cows.

MATERIAL AND METHODS

The study was conducted in 944 Holstein cows housed in 5 cattle farms in the Sliven region Bulgaria. All cows from the five farms culled in the period 2012–2018 with milk yield data for the first lactation (for standard lactation - from 240 to 305 days in milk) were included in the study. The farms surveyed were in a region with identical climatic and forage conditions - Southeast Bulgaria. The feeding of the cows and replacement heifers was based on corn silage, hay and green forage (seasonal) and compound feed. Animals from all farms were not grazed. Cows in farms 2 and 5 were housed in free stall barns and in the other three - under the conditions of bedded pack housing system. All cows were milked in a milking parlor 'Herringbone' type, with number of places corresponding to farm capacity. All farms produced their own replacement heifers. The rearing of female calves and heifers was the same in all farms. During the preweaning period calves were housed in individual hutches outdoors and during the rest of the periods – they were group housed on deep straw bedding, subject to the requirements for technological sizing of group stalls, depending on the age of the animals. The AFC was calculated from the date of birth to the date of the first calving, in months. The longevity was calculated as the difference between date of birth and date of culling of the cow, and the productive life, respectively - as the difference between the date of culling and the date of first calving. Both traits are presented in years.

For better approximation in data processing, the AFC is represented in classes, respectively: 1 – up to 24 months, 2 – from 25 to 27 months, 3 – from 28 to 30 months, 4 – from 31 to 33 months, 5 – from 34 to 36 and 6 – over 37 months. To study the relationship between FLMY and duration of productive life, it is presented in classes respectively: 1 – up to 1 year, 2–1 to 2 years, 3–3 to 4, 4–5 to 6 and 5–7 and more years.

The classes of FLMY are respectively: 1 – up to 4,000 kg, 2 – from 4,001 to 6,000 kg, 3 – from 6,001 to 8,000 kg, 4 – from 8001 to 10,000 kg and 5 – over 10,001 kg.

For the basic statistical processing, the corresponding modules of software packages of MS EXEL and STATISTICA of Stat Soft were used.

The following models were used to determine the degree of influence of the different factors and to derive reliable models:

$$Y_{ijkl} = \mu + H_i + AFC_j + H \cdot AFC_k + e_{ijkl} \quad (1)$$

where Y_{ijkl} – is the depended variable(first lactation milk yield); μ – is the population mean; H_i – is the i -th effect of the herd; AFC_j – is the j -th effect of the age at first calving; $H \cdot AFC_k$ – is the k -th related effect of the herd and age at first calving; e_{ijkl} – is the effect of the not included random effects, except μ .

$$Y_{ijk} = \mu + AFC_j + ML_j + e_{ijk} \quad (2)$$

where Y_{ijk} – is the depended variable(longevity and productive life); μ – is the population mean; AFC_i – is the i -th effect of the age at first calving; ML_j – is the j -th effect of the FLMY; e_{ijk} – is the effect of the not included random effects, except μ .

By analysis of variances (ANOVA) for each model by classes of fixed factors are evaluated the least squares of means (LSM), representing the sums of squares calculated as deviation from the mean value of the trait derived from the model.

RESULTS AND DISCUSSION

Table 1 presents the main statistics for the traits studied - FLMY, AFC, longevity and productive life by herds. The average AFC for all culled cows included in the study was 29.75 months. The variation of AFC across herds was not large (the difference was about 2 months), although the differences were statistically significant between herds with higher and lower AFC. The lowest was the average AFC for cows from herd 1–28.32 months and the highest for herd 3–30.84 months.

Table 1. Average values for FLMY and functional traits by herds

Herds	n	AFC, months	FLMY, kg	Longevity, years	Productive life, years
		$\bar{x} \pm SE$	$\bar{x} \pm SE$	$\bar{x} \pm SE$	$\bar{x} \pm SE$
1	226	28.32 ± 0.29^{abc}	$6,748.91 \pm 98.29^{abcd}$	5.14 ± 0.10^{ab}	2.74 ± 0.09^{abc}
2	83	30.75 ± 0.43^{ad}	$6,057.43 \pm 122.85^{ae}$	5.92 ± 0.15^{ac}	3.31 ± 0.16^a
3	33	30.84 ± 0.81^{be}	$5,899.09 \pm 315.20^{bfg}$	5.31 ± 0.32^d	2.78 ± 0.31^d
4	78	28.71 ± 0.31^{def}	$6,137.54 \pm 129.78^{cfh}$	6.06 ± 0.19^{bdf}	3.70 ± 0.19^{bde}
5	524	30.30 ± 0.17^{cf}	$8,646.00 \pm 48.42^{degh}$	5.32 ± 0.06^{cf}	2.83 ± 0.06^{ce}
Average	944	29.75 ± 0.13	$7,660.94 \pm 54.41$	5.39 ± 0.05	2.92 ± 0.05

a,b,c,d – differences between herds with identical letters are statistically significant at $P < 0.05$.

A 24-month AFC is considered as optimal for maximizing FLMY (Nilforooshan and Edriss, 2004), and achieving higher production profitability (Ghavi Hossein-Zadeh, 2011; Wathes et al., 2014). In fact, this target is rarely achieved in the various countries and the average AFC ranges from 24.5 to 31 months. Cooke et al. (2013) indicate that within the UK, the industry-recognized target for AFC is 24 months. Nevertheless, Eastham et al. (2018) indicate that the average AFC for Holstein heifers calved in the period 2006–2008 in the UK was 29.1 months. Cole & Null (2010) indicate for Holstein

breed in US AFC of 26 months, Haworth et al. (2008) for Australia - 28.8 months, Wu et al. (2012) in China - 29.3 months.

In our country over the years, several studies have been conducted on AFC in Black-and-white Holstein cattle. Gergovska & Yordanova (2011) found an average AFC of 29.7 months in 1460 Black-and-white cows calved in the period 1995–2006. Lower average AFC in Bulgaria was reported by Penev et al. (2014) in 818 Black-and-white cows from 7 farms - 26.6 months, with variations from 25 to 28 months by farms.

Fig. 1 shows the percentage of cows depending on the AFC. The highest percentage of cows calved for the first time at 25–27 and 28–30 months of age, respectively 26.2 and 26.6%. Quite a high percentage of cows have calved for the first time at a high age - 31 months or more, respectively 35.7%. Only 11.5% of the cows in the studied herds have calved at 24 months of age or less. The high percentage of heifers calved at over 34 months of age was due, on the one hand, to the failures in the management of the herds and, on the other, to the subjective decisions of the owners. Some owners deliberately postpone the first insemination of the heifers to a later age because of fear of negative consequences associated with calving and productivity due to the early conception. Such concerns were also indicated by Pirlo et al. (2000) among Italian farmers. Other reason is the neglected feeding and housing of replacement female calves and heifers, leading to delay of reaching the desired live weight and development for conception. Moreover, traits related to the development of young animals such as live weight and conformation traits were not controlled on our farms. Popova (2003) indicate that the practice of relatively late conception of heifers in Bulgaria (on age 16–18 months) was mainly consequence of inadequate feeding.

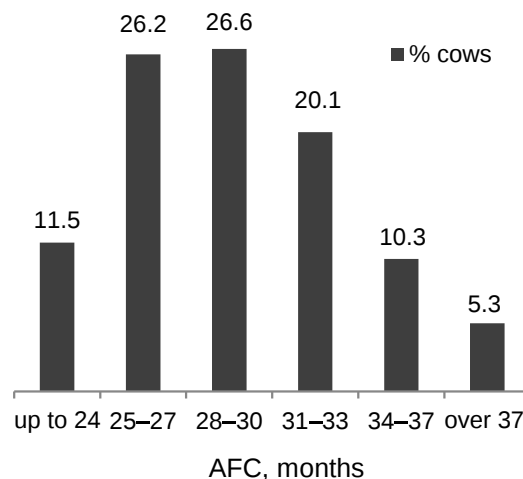


Figure 1. Percentage of cows depending on AFC.

Eastham et al. (2018), in a study covering 6,985 farms in UK report an average AFC for all heifers of 29.1 months, with only 12.3% calved for the first time at 24 months of age or younger and 40.9% calved for the first time at age of 30 months or older. Similar results reported and Sherwin et al. (2016), from other smaller scale British research where the average AFC was 29.6 months, with 35.9% of heifers calved for the first time at age over 30 months.

Sawa et al. (2018) in a study covering 10% of cows in Poland found that the percentage of cows calved before reaching the age of 22 months was the lowest (2.1%). The proportion of the cows calved for the first time at 24.1–26.0 and 26.1–28.0 months was considerable, 30.7% and 22.4%, respectively, and 9.1% of cows calved for the first time at the age of 30 months.

Fig. 2 presents the percentage of cows from the two extreme AFC groups - the youngest - 24 and less months and the oldest - over 34 months by herds. The data shows

a large difference in the percentage of cows from the two age groups in the individual herds. With the highest percentage of heifers with AFC of 24 months or less was herd 1–26.1%, and with the lowest in herd 4 - only 2.6%. In the other three herds, the proportion of heifers with AFC up to 2 years of age was similar and was up to 10%. This definitely shows the reluctance and lack of interest of the owners for the early conception of replacement heifers. On the other hand, in herd 3 there were a very high percentage of heifers with AFC over 34 months - 27.5%. This was the farm with the lowest average milk yield per a primiparous - 5,899.09 kg. With the lowest proportion of such animals were herds 5 and 4, respectively 1.5 and 3.3%. These large differences by herds were definitely related to the subjective decisions of the owners.

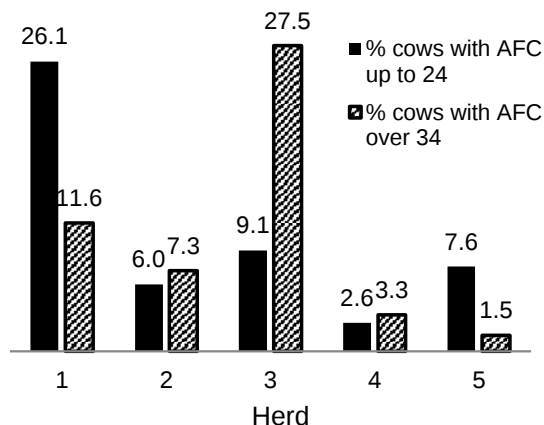


Figure 2. Percentage of cows with AFC up to 24 and over 34 months by herds.

The average FLMY of the herds included in the study was 7,660.94 kg, with significant herd variation,

Table 1. The highest milk yield was in primiparous of herd 5 - 8,646.0 kg. This was the largest farm with the highest milk yield per a cow. The milk yield was the lowest in primiparous from herd 3 - 5,899.09 kg, which was also with the smallest capacity. For the other 3 herds, the average milk yield was with values from 6,057.43 to 6,748.91 kg.

Table 2 shows the result of the analysis of variance for the effect of the two studied factors - herd and AFC on FLMY. The herd had effect with a high significance ($P < 0.001$), while the AFC effect and the associated herd*AFC effect were with less degree of significance ($P < 0.05$). The reported significance of the associated herd*AFC factor was related to the presented difference in the variation of the age classes by herds, Fig. 2.

Table 2. Analysis of variance for the influence of the herd and AFC on FLMY

Source of variation	Degrees of freedom (n-1)	FLMY, kg		
		MS	F	P
Total for the model	29	10,546	28.51	***
Herd	4	1,996	131.80	***
AFC	5	4,408	2.91	*
Herd*AFC	20	2,619	1.73	*
Error	914	1,514		

* – significance at $P < 0.05$; ** – significance at $P < 0.01$; *** – significance at $P < 0.001$; – no significant effect.

Fig. 3 shows the LS-means for FLMY depending on the AFC of the primiparous. The highest FLMY was reported in the primiparous with AFC 28–30 months - 7,860.8 kg, followed by those with AFC 31–33 months - 7,773.1 kg. The mean FLMY gradually decreased with the increase of AFC over 33 months, with 297.6 kg lower FLMY in primiparous with AFC over 37 months compare to the highest average milk yield for primiparous with AFC 28–30 months. The lowest FLMY was reported in primiparous with AFC of ≤ 24 months - 7,322.8 kg. The mean milk yield of the primiparous with AFC ≥ 37 months was also relatively low, almost equal to the mean milk yield of the primiparous with AFC ≥ 37 months - 7,526.7 kg. The mean FLMY of

the cows from the two youngest age classes was lower by 538 and 334.1 kg, respectively, compared to the highest FLMY in the class with AFC 28–30 months. These results clearly indicate an underestimation of management, especially with regard to the feeding of young replacement calves and heifers, whereby younger heifers do not reach the desired optimal levels of live weight and body condition at the first calving.

Several authors have found that cows' age at first calving influences milk yield for standard lactation (Ettema & Santos, 2004; Mohd Nor et al., 2013). An increase in milk yield at a greater AFC is associated with an increase in the body size of the primiparous and the development of the mammary glands (Mohd Nor et al., 2013). The authors found that milk yield has increased significantly in primiparous that have calved at age of 23 and 25 months. In primiparous that have calved at a later age, the increase in milk yield was less pronounced.

Eastham et al. (2018) found that the lowest predicted average milk yield for lactation (6,617 kg) was reported for cows with an AFC of 21 months, considerably lower than any other age class. Heifers with AFC of 36 months had the highest predicted average milk yield (7,774 kg), but it was not significantly higher than that in heifers with AFC of 34–42 months.

According to Meyer et al. (2004) data on the effect of lower AFC on milk yield for first lactation in Holstein cows in the USA were contradictory. Some authors found no effect, while others reported a negative effect. Most studies suggested that a decrease in AFC from 24.7 to 21.9 months results in an approximately 4.8% reduction in first lactation milk yield. The authors indicated that the biology associated with the interaction between low AFC and FLMY was difficult to identify and quantify. This is because a decrease in AFC is often associated with higher pre-pubertal daily growth/gain, reduced live weight at calving, or both, which appear to affect future milk yield. According to Dobos et al. (2001) with increasing AFC by one month during the first three lactations cows are 56.7 L milk, 1.78 kg milk fat, 1.45 kg milk protein and 3.23 kg fat + protein over the first 3 lactations.

Fig. 4 shows the inverse dependence, the mean AFC is determined depending on the FLMY (in classes). The average AFC of the cows with low FLMY - up to 4,000 kg was highest - 33 months. The lowest was the average AFC of cows with a FLMY from 4,001 to 6,000 kg. Primiparous with a milk yield of more than 8,000 kg had an average AFC of about 30 months. These results mainly show that the very high AFC does not favor the higher milk performance on first lactation.

The studies of other authors on the relationship between AFC and FLMY also are contradictory, the reasons for this being the differences in the management applied in the studied populations. Curran et al. (2013) concluded that the AFC between 23 and 30

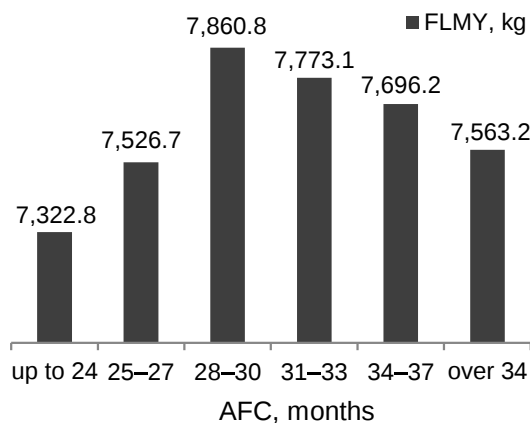


Figure 3. LS-mean values for FLMY (kg) depending on AFC (months).

months did not cause differences in milk yield of the primiparous and that calvings between 20 and 22 months were associated with lower milk yield, whereas Cooke et al. (2013) found no significant effect of AFC on the milk yield of the primiparous.

The average longevity for the cows included in the study was 5.39 years, and although significant differences were reported between the average values for the herds, the differences were small, Table 1. With the highest longevity were the cows from herd 4–6.06 years and with the lowest in herd 1–5.14 years, with difference being less than 1 productive life of all cows was 2.92 years. Again, the variation in this trait was within 1 year, year. Similar results were reported for the trait productive life. The average duration of although significant differences by herds were reported. With the longest productive life were the cows in herd 4–3.70 years and with the shortest in herd 1–2.74 years.

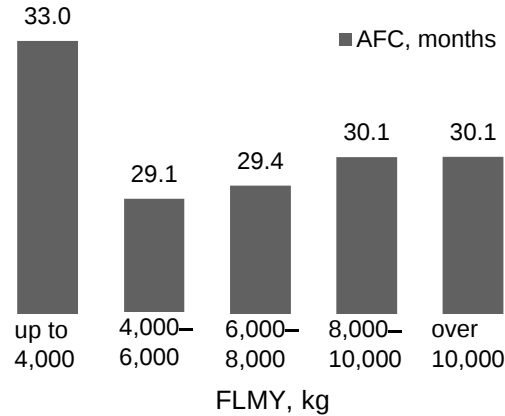


Figure 4. Average AFC (months) depending on FLMY (kg).

Table 3. Analysis of variance for the influence of AFC and FLMY on the functional traits

Source of variation	Degrees of freedom (n-1)	Longevity			Productive life		
		MS	F	P	MS	F	P
Total for the model	9	9.103	4.38	***	2.839	1.318	*
AFC	5	16.058	7.743	***	3.228	1.576	-
FLMY	4	1.17	0.565	-	2.425	0.041	*
Error	934	2.074			2.047		

* – significance at $P < 0.05$; ** – significance at $P < 0.01$; *** – significance at $P < 0.001$; - no significant effect.

As shown on Table 3 a statistically significant effect of AFC ($P < 0.001$) was found only on longevity, whereas the productive life was significantly influenced by FLMY ($P < 0.05$).

Fig. 5 shows the LS-means for the two traits - longevity and productive life depending on the cows' AFC. Although the AFC does not have a significant effect on productive life, the presentation of the mean values of the two traits gives a clearer picture of the relationship between them. From the presented LS - means a tendency

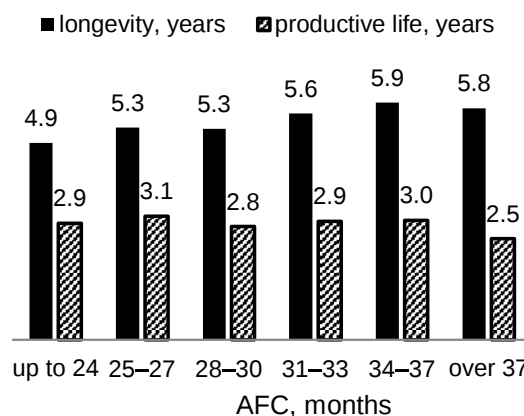


Figure 5. LS-mean values for longevity and productive life (years) depending on AFC (months).

for longer longevity was observed for cows with AFC 34–37 months and over 37 months - 5.9 and 5.8 years, respectively. The lowest were the mean values for longevity in cows calved at the lowest AFC up to 24 months - 4.9 years. No such clear trend was observed in the trait productive life. The shortest productive life was reported for cows with an AFC of over 37 months - 2.5 years. In other age classes a certain pattern was not observed, length of productive life ranged from 2.8 to 3.1 years. From the results presented, it can be concluded that the longer longevity for cows with AFC over 34 months mainly due to the unproductive part of their lives - until first calving.

Sawa et al. (2018) found a very low correlation between AFC and longevity ($r = 0.062^{**}$), also noting that the longer life is a result of a longer unproductive life (until first calving), and not of a longer productive life. Similar low (0.039–0.061) but significant correlation coefficients have been reported previously by Sawa & Bogucki (2010) and Do et al. (2013) ($r = 0.0131$).

The possibility of increasing the productive life of cows is of particular interest to livestock farmers. In their study, Sawa et al. (2018) found that the longest productive life (3.54 years) was typical for cows that calved for first time at age of 22.1–24.0 months, and for the other groups the productive life decreases to 3.49 years in cows with early AFC and up to 2.94 years with higher AFC. Similar trends for reduced productive life have been reported by Sawa & Bogucki (2010) and Jankowska et al. (2014).

Zavadilova & Stipkova (2013) and Olechnowicz et al. (2016) also report shorter productive life in cows with higher AFC. According to Cielava et al. (2017), the AFC has a significant effect on the life of cows, finding that the difference between the longevity of cows calved for the first time at < 24 and > 30 months is 1.4 years (5.9 vs. 7.3 years). In turn, Adamczyk et al. (2017) reported that the productive life of cows that calved before 24 months of age decreased compared to those that calved for the first time at age > 31 months, from 5.9 to 5.4 years.

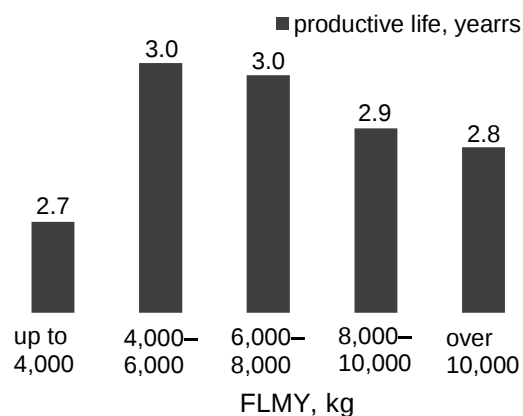


Figure 6. LS-mean values for productive life (years) depending on FLMY (kg).

Fig. 6 shows the LS - means for the productive life of cows, depending on their FLMY. With the highest mean productive life - 3 years were cows with a FLMY of 4,001–6,000 and 6,001–8,000 kg. Cows with FLMY up to 4,000 kg had the shortest productive life - 2.7 years. A trend of shorter productive life was also observed in cows with over 10,000 kg FLMY (2.8 years). The results obtained suggest that cows with low FLMY were culled for various reasons, including various diseases that led to the reported low milk yield. The reported tendency for shorter productive life in cows with very high FLMY more than 10,000 kg is a prerequisite for exhaustion in young animals with high first lactation productivity.

Fig. 7 shows the inverse relationship - the average FLMY in cows with different duration of productive life. Cows with the shortest productive life - up to 1 year had the lowest average FLMY – 6,437.1 kg. The cows with the highest FLMY 7,915.5 and 7,891.1 kg had a productive life of 3 and 2 years, respectively. Cows with a long productive life of more than 6 years had an optimal average FLMY - 7,364.3 kg.

These results support the view that low milk yield primiparous are often culled within the first lactation, i.e. up to 1 year after calving. Primiparous with very high first lactation productivity had a relatively short productive life (2–3 years), and the longest productive life, over 6 years, was reported in cows with medium-high FLMY.

Usually, 1 to 1.5 lactations are needed to cover the cost of rearing the replacement heifers, therefore FLMY and longevity affect the payback period of the rearing costs (Boulton et al., 2017). Moreover, cows that are culled or die shortly after the first calving will not cover their costs of rearing, leading to large losses (Fodor et al. 2019).

Both very low and high AFC are associated with lower first lactation cow productivity and shorter productive life. From an economic point of view, losses are greater when keeping a high AFC in heifers, which increases the cost for housing them, and the lower productivity and longer productive life reduce the probability of covering them.

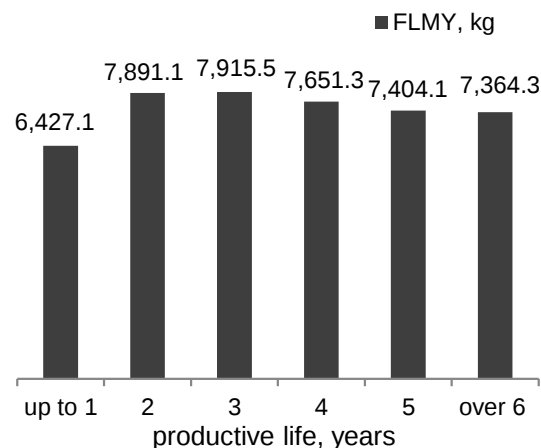


Figure 7. Average FLMY (kg) depending on productive life (years).

CONCLUSIONS

The average AFC for the herds studied is relatively high - 29.75 months with a slight variation by the herds (about 2 months). The highest percentage of cows (52.8%) - are calved for the first time at 25–30 months. The highest FLMY was reported in cows with AFC 28 to 30 months – 7,860.8 kg, and the lowest in cows with AFC 24 and less months. Cows with both very low and high AFC had lower FLMY. The longer longevity for cows with higher AFC (over 34 months) was due to the greater unproductive share of their life (until first calving). The cows with the lowest average FLMY (up to 4,000 kg) had the shortest productive life. There was a tendency for shorter productive lives also for cows with very high FLMY (over 10,000 kg).

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