

ANALYSIS OF HEIFERS REARING FROM DIFFERENT LACTATION DAIRY COWS

Indra Eihvalde, Daina Kairiša

Latvia University of Agriculture

indra.eihvalde@gmail.com; daina.kairisa@llu.lv

Abstract

The research was conducted in Latvia University of Agriculture Research and Study Farm ‘Vecauce’ in 600 dairy cows herd, in the period from 2009 to 2013. Within the framework of the research, growth indicators (from birth till the first delivery) of 102 dairy cow calves were analysed. Live weight and hip height of the heifers were found out at birth, at the age of 6 and 12 months, at first insemination and first calving. Heifers born to primiparous cows in both breed groups had notably lower live weight (42.0 and 42.4 kg), as compared to the 4th group heifers born to mature cows ($p < 0.05$). At the age of one year, the greatest weight among the red breed animals was recorded for the 4th group heifers born to mature cows (on average 354.8 ± 7.09 kg), while in Holstein breed those were heifers born to mothers calving on average for the 2nd time (on average 363.0 ± 6.47 kg). The 4th group heifers born to mature Holstein cows had notably greater hip height at birth – on average 78.1 ± 0.9 cm ($p < 0.05$). Heifers of red and Holstein breeds on average were inseminated at the age of 14.6 – 14.8 months as they reached live weight 395 – 396.5 kg. Heifers of red breeds on average calved at the age of 25.8 months, whereas Holstein heifers - of 26.4 months. The research aimed at analysing growth rates of heifers born to dairy cows at different age.

Key words: heifers, weight, hip height, insemination age, calving age.

Introduction

Under intensive farming, dairy cows on average are used for 2 – 3 lactations (Maia *et al.*, 2013; Jouzaitiene *et al.*, 2015). As a result, one third of calves is born to primiparous cows, which are not grown-ups yet. Newborn calves born to primiparous cows often are smaller than calves born to older cows (Pietersma *et al.*, 2006; Kamal *et al.*, 2014). Several researches conducted prior show that live weight of calves at birth affects further growth and development thereof (Arthington *et al.*, 2000), whereas live weight of newborn calves is influenced by several factors, e.g., breed, calving season, nutrition of mother, health status, etc. Suitable breeding of heifer is a precondition for healthy and highly-productive cattle used for herd restocking or expansion. Optimal breeding of calves reduces costs, by ensuring high productivity, reproduction, and long cattle life (Raguz *et al.*, 2011). Development of calves at various rearing periods differs; it is influenced by calve’s physiological characteristics, housing and nutrition conditions. Insufficiently nourished heifers lag behind in growth, thus first insemination thereof will be delayed, whereas

overfed heifers have lower conception indicators, and they may have difficult delivery (Vacek *et al.*, 2015). The research aimed at analysing breeding indicators (till the first delivery) of different breeds heifers born to dairy cows at different age.

Materials and Methods

The research was conducted in Research and Study Farm ‘Vecauce’ of Latvia University of Agriculture in a herd consisting of 600 dairy cows. Heifers were bred under the same conditions, by separating them till the age of three months and grouping afterwards. The research period covered the time period from 2009 to 2013. During the period, 147 heifers were born, 45 of them were excluded from the research due to various reasons. In the red breed group 53.3% of heifers were excluded, and in Holstein group – 46.7%. Out of the heifers excluded 27% were born to primiparous cows and cows in their 3rd lactation, 24% – to cows in their 4th lactation, and 22% – to cows in their 2nd lactation.

Dairy cows were grouped by the number of calving times, but newborn heifers – were grouped by a breed or breed group (Table 1).

Table 1

Research scheme

Group No	Calving time	Number of newborn calves	Breed or breed group of newborn calves			
			Red breeds, n	%	Holstein breed, n	%
1.	1 st	27	9	19.6	18	32.1
2.	2 nd	28	13	28.2	15	26.8
3.	3 rd	26	12	26.1	14	25.0
4.	4 th and up	21	12	26.1	9	16.1
Total:		102	46	100	56	100

Table 2

Factors influencing live weight of calves

Characteristics		Factors	
		mother calving time	heifer breed
		p – value	
Live weight, kg	at birth	***	***
	at age of 6 months	***	***
	at age of 12 months	***	***
	at first insemination	***	***
	at first calving	***	***
Hip height, cm	at birth	***	***
	at age of 6 months	***	***
	at age of 12 months	***	***
	at first insemination	***	***

*** p<0.001, factor has significant influence on live weight and hip height of calves.

The group of red breeds includes Latvian Brown and Danish Red heifers, while Holstein breed group – Holstein black and white and Holstein red and white cows. The research covered 46 heifers of red breed and 56 heifers of Holstein breed.

In several researches it has been pointed out that, live weight and growth indicators of red breeds and Holstein breed cattle differ (Pietersma *et al.*, 2006; Kamal *et al.*, 2014); therefore, the results acquired were analysed for each breed separately. With the help of verified measuring instruments heifer live weight and hip height at birth, at the age of six and twelve months, at first insemination and first calving was found out.

Analysis of the data acquired was based on the indicators of descriptive statistics: arithmetical mean and standard error. Analysis of the factors influencing the research data was performed by using univariate analysis of variance. Significant differences among factor gradation classes were found with the t-test; in tables they have been indicated with a superscripted letter and symbol (A; B – between breed groups, a; b – between research groups, * between rearing groups: to 6 months and after 6 months). Research correlations were characterised with linear correlation coefficient.

Results and Discussion

When initiating analysis of the data acquired, the influence left by mother calving time and heifer breed on live weight and hip height was found out (Table 2).

The results acquired show that live weight and hip height of calves at different rearing periods are influenced by calving time of a mother and breed or breed group of a heifer (p<0.001).

Other researches have shown that during the first twelve months of life, live weight of heifers increases

rapidly (Cooke *et al.*, 2013) – the same phenomenon was observed also in this research (Table 3).

Live weight of red breed heifers at birth was between 42.4 and 46.3 kg; for heifers of the 4th group it was notably greater – 46.3 ± 0.81 kg, while heifers of the 1st group were by 3.9 kg lighter than 4th group heifers. At the age of six months live weight of calves levelled up and did not differ significantly; however, greater live weight still was observed for 2nd and 4th group heifers – 187.5 ± 5.09 kg and 187.6 ± 5.08 kg, respectively. At the age of one year heifers of the 4th group were remarkably heavier (345.8 ± 7.09 kg) than heifers of the 1st and 3rd groups (p<0.05).

Similar indicators at birth may be observed for Holstein breed heifers. Notably greater live weight was recorded for the 4th group heifers – on average 46.6 ± 1.07 kg (p < 0.05). The results acquired within the research show that Holstein heifers at birth were heavier than it was stated in other researches (Spiegler *et al.*, 2014; Passille, Rabeyrin, & Rushen 2014; Kamal *et al.*, 2015), indicating that live weight of Holstein calves at birth on average comprised 39.8 – 41.4 kg. At the age of six months no significant differences were observed among groups of Holstein breed heifers, similarly as it was with the heifers of red breeds. However, heifers of 3rd and 4th groups were heavier – 193.1 ± 4.78 kg and 201.3 ± 8.63 kg, respectively. Data of a research conducted in the United Kingdom show that Holstein breed heifers born to primiparous cows at the age of six months weighted on average 183.3 kg (Cooke *et al.*, 2013), but weight thereof in this research on average constituted 185.2 kg – it is 1.9 kg more. At the age of one year notably greater live weight was recorded for the 2nd group heifers – on average 363.0 ± 6.47 kg, and it is 30 kg more than live weight of the 1st group heifers (p<0.05).

Table 3

Changes in live weight of calves of red and Holstein breeds (kg)

Heifer age	Research group			
	1.	2.	3.	4.
	Red breeds group			
At birth	42.4 ± 1.13 ^a	45.2 ± 1.03 ^{a,b,A}	44.1 ± 1.41 ^{a,b}	46.3 ± 0.81 ^b
At the age of 6 months	178.9 ± 5.73	187.5 ± 5.09	183.0 ± 4.93 ^A	187.6 ± 5.08
At the age of 12 months	331.1 ± 9.94 ^a	341.6 ± 7.88 ^{a,b}	324.3 ± 6.31 ^a	345.8 ± 7.09 ^b
Holstein breeds group				
At birth	42.0 ± 0.78 ^a	42.9 ± 0.72 ^{a,B}	44.5 ± 1.09 ^b	46.6 ± 1.07 ^b
At the age of 6 months	185.2 ± 4.26	185.6 ± 4.59	193.1 ± 4.78 ^B	201.3 ± 8.63
At the age of 12 months	332.9 ± 7.58 ^a	363.0 ± 6.47 ^b	335.9 ± 7.80 ^{a,b}	338.1 ± 11.51 ^{a,b}

^{a,b,c} – characteristic feature notably differs among research groups; p<0.05
^{A,B} – characteristic feature notably differs between breed groups; p<0.05

The results acquired meet the findings of other researchers and prove that heifers born to primiparous cows tend to have smaller calves (Kamala *et al.*, 2014). Live weight was similar for the newborn calves born in the red breed group and ones born in the Holstein group, still red breed heifers of the 2nd group were by 2.3 kg heavier than Holstein heifers (p<0.05). At the age of six months Holstein heifers of the 3rd group were by 10.1 kg heavier than red breed heifers (p<0.05). At the age of one year live weight of calves evened out and did not differ significantly among breeds.

Heifer growth rate is characterised by the daily live weight gain (Table 4). Scientist Shamay and his colleagues (2005) believe that, desirable daily weight gain of dairy cows from birth till insemination on average accounts for 700 g.

Live weight gain of red breed heifers aged up to six months did not differ significantly, but at the age

6 – 12 months daily live weight gain of the 4th group heifers was by 94 g greater than one observed for the 3rd group heifers (p<0.05). Red breed heifers of the 1st, 2nd, and 3rd group gained weight evenly in both rearing periods, and no notable differences were recorded; however, the 4th group heifers aged 6–12 months grew by 100 g more than heifers in the age group 0 – 6 months (p<0.05).

Daily live weight gain of Holstein breed heifers aged up to six months on average constituted 818.3 g, while of heifers in the second age group – on average 825.3 g daily. Such results differ from the findings of other researchers (Cooke *et al.*, 2013) showing that average daily live weight gain of Holstein-Freeze breed heifers aged up to six months comprises - 1094 g, while after the age of six months – 764 g. Differing results were published also by Kertz, Prewitt, & Ballam, (1987), pointing out that, in the research conducted

Table 4

Daily live weight gain of red and Holstein breed calves (g) by research period

Heifer age	Research group			
	1.	2.	3.	4.
	Red breed group			
0 – 6 months	758 ± 33.1	791 ± 28.1	772 ± 28.5	785 ± 27.8 *
6 – 12 months	846 ± 47.5 ^{a,b}	856 ± 53.4 ^{a,b}	785 ± 35.2 ^a	879 ± 30.4 ^{A,b,*}
Holstein breed				
0 – 6 months	795 ± 23.9	793 ± 24.9*	825 ± 26.0	860 ± 45.1
6 – 12 months	821 ± 37.4 ^a	930 ± 40.7 ^{b*}	794 ± 46.4 ^a	760 ± 46.2 ^{B,a}

^{a,b,c} – live weight gain differs notably among research groups; p<0.05

^{A,B} – live weight gain differs notably among breeds; p<0.05

* – daily live weight gain differs notably within the breed between rearing periods (to 6 month and after 6 month); p<0.05

Table 5

Changes in hip height of red and Holstein breed heifers (cm) by research period

Heifer age	Research group			
	1.	2.	3.	4.
	Red breed group			
At birth	78.2 ± 1.62	79.8 ± 1.76 ^A	77.5 ± 1.39	78.4 ± 1.63
At the age of 6 months	110.8 ± 1.62	110.7 ± 1.12	109.5 ± 0.50 ^A	110.3 ± 0.75
At the age of 12 months	126.3 ± 1.27 ^{ab}	127.3 ± 0.63 ^a	125.3 ± 0.68 ^b	126.0 ± 0.89 ^{ab}
	Holstein breed			
At birth	75.1 ± 0.82 ^a	75.1 ± 1.04 ^{a,B}	76.4 ± 0.60 ^{b,a}	78.1 ± 0.9 ^b
At the age of 6 months	109.8 ± 0.77	110.7 ± 0.99	111.1 ± 0.64 ^B	111.9 ± 1.42
At the age of 12 months	126.3 ± 0.75	127.5 ± 1.02	125.6 ± 0.80	125.8 ± 1.49

^{a,b} – characteristic feature differs notably among the research groups; $p < 0.05$

^{A,B} – characteristic feature differs notably between the breed groups; $p < 0.05$

thereof Holstein heifers aged up to six months gained on average 830 – 930 g daily, while heifers aged 6 – 12 months – on average 1000 g daily. In this research daily live weight gain of Holstein heifers aged up to six months did not differ significantly among groups and varied between 793 g and 860 g, while for heifers aged 6 – 12 months remarkably greater daily live weight gain was recorded for the 2nd group heifers – on average 930 ± 40.7 g ($p < 0.05$). Comparison of daily live weight gain by rearing period shows notable increase in growth rate of the 2nd group heifers – on average by 137 g daily ($p < 0.05$).

Between the breed groups significantly higher growth rates were recorded for red breed heifers of the 4th group – on average 879 ± 30.4 g daily, comprising 119 g daily more than weight gain of the 4th group Holstein heifers ($p < 0.05$).

Size of an animal is characterised by wither and hip height thereof. Insufficient or unbalanced nutrition of heifers leads to lack in reaching desired size. Wither height of the research heifers closely correlated with hip height, $r = 0.83$; therefore, research covered only analysis of hip height (Table 5).

Within the framework of the research, it was found out that hip height of red breed heifers at birth on average constituted 78.5 cm and did not differ notably among the groups. However heifers of the 2nd group were of a greater height – on average 79.8 ± 1.76 cm. Also, at the age of six months hip height of heifers did not differ significantly; nevertheless, heifers born to primiparous cows were of greater height – hip height thereof on average constituted 110.8 ± 1.62 cm. At the age of one year notable differences in hip height were recorded for the 2nd group heifers, hip height of which was by 2.0 cm greater than one of the 3rd group heifers ($p < 0.05$).

Within the Holstein breed group, significantly greater hip height at birth was observed for the 4th

group heifers – on average 78.1 ± 0.9 cm ($p < 0.05$). The findings are confirmed also by results of other researches indicating that Holstein breed heifers from primiparous cows were born on average with 75.5 cm high hips, while hip height of older cows on average constituted 76.6 cm (Kamal *et al.*, 2015). At the age of six months Holstein heifers in all groups had similar hip height; however, the indicator in the 4th group was higher – on average 111.9 ± 1.42 cm. Similarly as in the group of red breeds, also in the Holstein group at the age of one year heifers with higher hips were born in the 2nd group. Comparison of the results acquired between the breed groups shows that the 2nd group red breed heifers at birth had by 4.7 cm higher hips than the 2nd group Holstein heifers; moreover, live weight thereof at birth was greater as well. At the age of six months the 3rd group Holstein heifers were significantly higher – the hip height thereof on average comprised 111.1 ± 0.64 cm ($p < 0.05$).

Age at the first insemination in all research group met the optimum indicators – from 14 to 15 months – suggested by foreign scientists (Cooke *et al.*, 2013; Duplessis *et al.*, 2015; Vacek *et al.*, 2015) and animal breeding specialists in Latvia (Ciltsdarba programma..., 2012; Latvijas Holšteinas..., 2012).

In 2015, the average age of calves at the first insemination in Latvia was 15.8 months (Lauksaimniecības datu..., 2015); one of the research heifers of both breeds – on average 14.7 months.

Age at the first insemination is closely related to the live weight of heifer; optimally heifer has to reach 55% of the live weight of a mature cow (Duplessis *et al.*, 2015). For heifers of the red breeds the age at the first insemination varied between 14.2 (3rd group) and 14.9 (1st group) months, while average live weight – from 380.5 kg (1st group) to 415.1 kg (4th group). Notably greater live weight at the age of 14.7 months was reached by the 4th group heifers –

Table 6

Age, live weight, and hip height of red breed calves at the first insemination and calving

Indicators	Research group			
	1.	2.	3.	4.
At first insemination				
Age, months	14.9 ± 0.33	14.4 ± 0.31	14.2 ± 0.25	14.7 ± 0.26
Live weight, kg	380.5 ± 11.01 ^a	402.0 ± 7.66 ^b	381.9 ± 9.38 ^{ab}	415.1 ± 7.09 ^b
Hip height, cm	130.1 ± 1.83	131.0 ± 1.14	128.9 ± 0.85	130.8 ± 1.34
At first calving				
Age, months	27.0 ± 1.18 ^a	24.6 ± 0.43 ^b	25.6 ± 1.28 ^{ab}	25.8 ± 0.65 ^{ab}
Live weight, kg	610.0 ± 31.96	615.5 ± 27.40	598.8 ± 26.32	576.0 ± 24.17
Hip height, cm	142.8 ± 1.06 ^a	143.0 ± 0.8 ^a	143.9 ± 1.35 ^{ab}	146.7 ± 0.86 ^b

^{a,b} – characteristic feature differs notably among research groups; p<0.0

on average 415.1 ± 7.09 kg (p<0.05). In Canadian research conducted with Ayrshire breed heifers the first insemination was made at the age of 17.9 months, when live weight of the heifers comprised 400 kg (Pietersma *et al.*, 2006). In this research, red breed heifers for the first time were inseminated on average at the age of 14.6 months, as animal reached hip height 130.2 cm and 395 kg of live weight, that on average constitutes 66.9% of the live weight of mature red breed cow. The results acquired show that in this research heifers were inseminated by 3.3 months earlier than in the Canadian research.

Calving age is influenced not only by the heifer age at the first insemination, but also by the number of insemination times (Cooke *et al.*, 2013). Within the red breed group, remarkably later calving was observed for heifers born to primiparous cows – on average at the age of 27.0 ± 1.18 months. Insemination of these heifers was started at the age of 14.9 months and done on average 1.2 times that is the lowest number

of inseminations among red breed groups. Based on the results acquired, a conclusion may be made that, within the primiparous cow heifer group problems are faced in respect to conception.

Live weight of red breed heifers at the first calving on average comprised 576 – 615.5 kg. No significant differences were observed among the groups; however, greater weight was recorded for the 2nd group heifers – on average 615.5 ± 27.40 kg. First calving of the heifers of this group took place at optimum age, i.e., on average at the age of 24.6 months; the interval between the first insemination and the first calving on average lasted for 10.2 months, whereas average number of inseminations constituted 1.4 ± 0.24. Suitable live weight is not the only indicator important at calving, cow size has to be taken into consideration as well. Red breed heifers calve with an average hip height 144.1 cm – 3.1 cm more than stated in the Breeding Programme (Ciltstarba programma) for 2013 – 2017. Significantly greater hip height at

Table 7

Age, live weight, and hip height of Holstein breed calves at first insemination and calving

Indicators	Research group			
	1.	2.	3.	4.
At first insemination				
Age, months	14.6 ± 0.38	14.6 ± 0.39	14.6 ± 0.29	15.3 ± 0.37
Live weight, kg	401.7 ± 8.28	404.1 ± 5.55	397.7 ± 7.39	382.5 ± 14.08
Hip height, cm	132.4 ± 0.87	133.9 ± 1.34	131.7 ± 1.09	133.9 ± 1.48
At first calving				
Age, months	26.1 ± 0.82 ^{a,b}	26.9 ± 0.84 ^a	24.9 ± 0.45 ^b	27.6 ± 1.65 ^{a,b}
Live weight, kg	610.0 ± 17.83	626.2 ± 19.76 ^a	572.2 ± 14.03 ^b	598.3 ± 34.82
Hip height, cm	145.7 ± 1.38	145.8 ± 1.25	143.7 ± 1.77	146.8 ± 1.89

^{a,b} – characteristic feature differs notably among research groups; p<0.05

calving was recorded for the 4th group heifers – on average 146.7 ± 0.86 cm, exceeding the indicator desirable for the breed by 3.1 cm ($p < 0.05$).

Canadian scientist Pietersma and others (2006) in their research on Ayrshire breed heifers found out that their first calving takes place at the age of 28 months, as cows have reached average live weight of 507 kg; while in this research heifers calved 2.2 months earlier and at that moment were by 93 kg heavier.

Holstein breed heifers for the first time were inseminated at the age of 14.8 months as they reached average live weight of 396.5 kg that is equal to 61.5% of live weight of mature Holstein cow and exceeds the indicators optimal for the breed by 6.5% (Table 7).

The greatest live weight at the age of 14.6 months was reached by the 2nd group heifers. In the Canadian research, Holstein heifers for the first time were inseminated on average at the age of 17.3 months as they reached average live weight of 464 kg (Pietersma *et al.*, 2006). Czech scientists emphasize that an important role in further productivity of a heifer is fulfilled by age at insemination and live weight. In their opinion, it is advisable to inseminate Holstein breed heifers at the age of 14 months as they reach live weight comprising 400 kg (Vacek *et al.*, 2015).

In this research, Holstein heifers calved on average at the age from 24.9 months (2nd group) to 27.6 months (4th group) and reaching live weight of 572.2 ± 14.03 kg and 598.3 ± 34.82 kg, respectively. Notable differences at the age of the first calving were recorded between the 2nd and 3rd group heifers – 2 month difference ($p < 0.05$). Pietersma and other researchers (2006) in research conducted with Holstein heifers found out that they calved on average at the age of 26.9 months as they reached live weight of 587 kg. Kamal and other scientists within the researched carried in Belgium and Germany farms discovered that heifers, which calved at the age 23.5 – 25.5 months, had higher reproduction and productivity indicators, as compared to heifers calving earlier or later than at this age (Kamal *et al.*, 2014). The findings are confirmed also by results obtained in other researches (Mohd Nor *et al.*, 2013).

In this research, the hip height of Holstein heifers at calving on average comprised 145.5 cm that meets indicators characteristic to mature Holstein cows.

Comparison of the results by breed group allows concluding that the age of calve at the first insemination does not differ notably, while significantly greater live weight was recorded for Holstein heifers of the 1st group – difference of 21.2 kg ($p < 0.05$). Significantly older age at the first calving was observed for Holstein heifers of the 2nd group (26.9 months) – difference of 2.3 months, as compared to the red breed 2nd group heifers ($p < 0.05$). Generally it may be concluded that Holstein heifers had shorter time interval between the age at the first insemination and calving – on average 10.3 – 12.3 months.

Conclusions

1. Heifers born to primiparous cows in both groups had smaller live weight, while at the age of six months it levelled among all research groups. In red breed group one-year-old heifers of the 4th group were heavier, while in Holstein group – heifers, mothers of which calved for the second time.
2. Hip height at birth recorded for heifers in the red breed group did not differ notably among the research groups, while the 4th group heifers born to mature Holstein cows had significantly greater hip height ($p < 0.05$). Comparison of the research group heifers by breed shows that red breed heifers, mothers of which calved for the second time, were born with a greater hip height ($p < 0.05$).
3. Heifers in the red breed group on average calved at the age of 25.8 months, while Holstein heifers calved on average 0.6 months later – at the age of 26.4 months. The fact may be explained by higher average number of inseminations and gestations – on average 1.7 times that is 0.2 times more than for red breed heifers.
4. Hip height at calving observed for Holstein breed heifers was similar in all groups, while in red breed group it was significantly greater for mature cows of the 4th group – on average 146.7 cm, exceeding hip height of a mature cow by 5.7 cm.
5. At insemination, research cows had 66.9% of mature red cow live weight and 61.5% of mature Holstein cow live weight, indicating that cows may have been inseminated earlier.

References

1. Arthington, J.D., Cattell, M.B., Quigley, J.D., McCoy, G.C., & Hurley, W.L. (2000). Passive immunoglobulins transfer in newborn calves feed colostrum or spray dried alone or as a supplement to colostrum of varying quality. *Journal of Dairy Science*, 83, 2834-2838. DOI: 10.3168/jds.S0022-0302(00)75183-6.
2. Ciltsdarba programma sarkano šķirņu govju selekcijā 2013-2017. gadam un tuvākajā nākotnē (2012). (The breeding program of red breed cows selection 2013-2017 and the near future). Retrieved February 9, 2016, from https://www.google.lv/?gws_rd=ssl#q=ciltsdarba+programma. (in Latvian).

3. Cooke, J.S., Cheng, Z., Bourne, N.B., & Wathes, D.C. (2013). Association between growth rates, age at first calving and subsequent fertility, milk production and survival in Holstein-Friesian heifers. *Journal of Animal Sciences*, 3(1), 1-12. DOI: 10.4236/OJAS,2013.31001.
4. Duplessis, M., Cue, R., Lefebvre, D., & Lacroix, R. (2015). Weight, height, and relative-reliability indicators as a management tool for reducing age at first breeding and calving of dairy heifers. *Journal of Dairy Science*, 98 (3), 2063-2073. DOI: 10.3168/JDS.2014-8279.
5. Juozaitiene, V., Anskiene, L., Banys, A., Rekešiuote, A., Šileika, A., Muzikevičius, A., Kantautaitė, J., Žoštautienė, V., & Juozaitis, A. (2015). Investigation of exterior traits dependence on the genotype of Lithuanian Black and White cows according to the degree of Holstein genes. *Veterinarija ir zootechnika*, 69 (91), 26-33. DOI: 1392-2130.
6. Kamal, M., Van Eetvelde, M., Bogaert, H., Hostens, M., Vandaele, L., Shamsuddin, M., & Opsomer, G. (2015). Environmental factors and dam characteristics associated with insulin sensitivity and insulin secretion in newborn Holstein calves. *Animal Sciences*, 9 (9), 1490-1499. DOI: 10.1017/S17517311150000701.
7. Kamal, M., Van Eetvelde, M., Depreester, E., Hostens, M., Vandaele, L., & Opsomer, G. (2014). Age at calving in heifers and level of milk production during gestation in cows are associated with the birth size of Holstein calves. *Journal of Dairy Science*, 97 (9), 5448-5458. DOI: 10.3168/jds.2014-7898.
8. Kertz, A., Prewitt, L., & Ballam, J. (1987). Increased weight gain and effects on growth parameters of Holstein heifer calves from 3 to 12 months of age. *Journal of Dairy Science*, 70 (8), 1612-1622. DOI: 10.3168/jds.S0022-0302(87)80189-3.
9. Latvijas Holšteinas šķirnes govju citsdarba programma 2013-2017. (2012). (Latvian Holstein cow breeding program 2013-2017). Retrieved February 9, 2016, from https://www.google.lv/?gws_rd=ssl#q=Hol%C5%A1teinas+%C5%A1%C4%B7irnes+ciltsdarba+programma. (in Latvian).
10. Lauksaimniecības datu centrs (2015). Piena pārraudzības rezultāti 2015. (Agricultural Data Centre. Milk recording in 2015). Retrieved February 9, 2016, from http://www ldc.gov.lv/upload/doc/republika_2015.pdf. (in Latvian).
11. Maia, R., Ask, B., Madsen, P., Pedersen, J., & Labouriau, R. (2013). Genetic determination of mortality rate in Danish dairy cows: A multivariate competing risk analysis based on the number of survived lactations. *Journal of Dairy Science*, 97 (3), 1753-1761. DOI: 10.3168/jds.2013-6959.
12. Mohd Nor, N., Mourits, M., Hogeveen, H., & Steeneveld, W. (2013). First-calving age and first-lactation milk production on Dutch dairy farms. *Journal of Dairy Science*, 96 (2), 981-992. DOI: 10.3168/jds.2012-5741.
13. Passille, A., Rabeyrin, M., & Rushen, J. (2014). Associations between milk intake and activity in the first days of a calf's life and later growth and health. *Animal Behaviour Science*, 10, 1-6. DOI: 10.1016/j.applanim.2014.10.002.
14. Pietersma, D., Lacroix, R., Lefebvre, D., Cue, R., & Wade, K.M. (2006). Trends in growth and age at first calving for Holstein and Ayrshire heifers in Quebec. *Canadian Journal of Animal Science*, 91, 325-336. DOI: 10.4141/A05-080.
15. Raguz, N., Jovanovac, S., & Gantner, V. (2011). Analysis of factors affecting the length of productive life in Croatian dairy cows. *Bulgarian Journal of Agricultural Science*, 17 (2), 232-240.
16. Shamay, A., Werner, D., Moallem, U., Barash, H., & Bruckental, I. (2005). Effect of nursing management and skeletal size at weaning on puberty, skeletal growth rate, and milk production during first lactation of dairy heifers. *Journal of Dairy Science*, 88 (4), 1460-1469. DOI: 10.3168/jds.S0022-0302(05)72814-9.
17. Spiegler, S., Kaske, M., Köhler, U., Meyer, H., Schwarz, F., & Wiedemann, S. (2014). Effect of feeding level of pregnant dairy heifers sired by one bull on maternal metabolism, placental parameters and birthweight of their female calves. *Animal Reproduction Science*, 146 (3-4), 148-156. DOI: 10.1016/j.anireprosci.2014.03.007.
18. Vacek, M., Krpakova, L., Syruček, J., Štipkova, M., & Janecka, M. (2015). Relationships between growth and body condition development during the rearing period and performance in the first three lactations in Holstein cows. *Czech Journal of Animal Science*, 60 (9), 417-425. DOI: 10.17221/8460-CJAS.