EFFECT OF GENOTYPE AND PRODUCTIVITY LEVEL ON SELECTED TRAITS OF LITHUANIAN BLACK AND WHITE COWS

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Abstract. The effect of genotype and herd productivity level on selected traits of 52432 cows was evaluated by data of the Lithuanian Black-and-White cattle improvement association. The average percentage of Holstein genes in cow's genotype (66.25±0.081%) has been estimated according to the records of cow's with complete 3 ancestor's generations pedigree information. We estimated that an increase of Holstein genes in cows' genotype is associated with growth of milk yield, fat and protein production (R^2=0.7305-0.852), but has a tendency to decrease a longevity of cows (R^2=0.6926), ($P < 0.001$). The growth of productivity level of herds was associated with an increase of the negative phenotypic correlation of cow's milk yield with fat, milk yield and protein, protein with longevity. The higher degree of Holstein genes was related with an increase of times of insemination, prolonged service period and calving interval of cows ($P<0.001$). The highest positive correlations of Holstein breed degree with investigated reproduction traits of cows was estimated in herds with a highest productivity level ($r = 0.40$ -0.45, $P < 0.001$).

Cows with a higher amount of Holstein breed genes in herds with a higher productivity level were taller, more capacious, with deeper chest width, straighter leg form and leg set angle, with moderately attached udder, udder cleft and teat length.

Keywords: productivity; reproduction; longevity; conformation traits; Lithuanian Black and White cattle; Holstein breed; genotype.

Introduction. Lithuania is small country in the European Union (EU) where the dairy cattle industry plays a considerable role in agriculture and economy. Holstein breed as one of the highest milk yielding breeds in the world was used in Lithuanian Black and White breed improvement program and milk cattle population with high share of Holstein genes was formed.

Internationalization and world globalization will lead to an even freer world dairy market and an enlargement of germplasm exchange in the world. This situation would be translated by an increased intensification and industrialization of production systems and will consequently have profound implications on production systems and the environment. However, the sustainable intensification requires appropriate use of genetic resources with an understanding of the limitations and opportunities of the production environment in which the animals will be maintained. The ability of farmers to respond to environmental conditions such as climate, feed base, food security, and consumer preferences should guarantee a sustainable livestock development (Hammami et al., 2009).

In recent years, a number of scientific studies estimated that the dairy cow productivity and culling reasons are very closely related to genotype of animals (Pachova et al., 2005; Meszaros, 2008; Sewalem et al. 2010), conformation traits of cows (Sanders et al., 2009, Forsback et al., 2010) and reproduction. It has been shown that the phenotypic antagonistic relationship between milk yield and reproductive efficiency is inversely related to the level of management (Laben et al., 1982). A decline in fertility is mainly associated with an increase in milk production and maybe partially explained by the negative energy balance observed during the early postpartum period. Therefore, evaluation of the body condition scores is an easy method for understanding the relationship between nutritional condition and reproductive performance (Dochi et al., 2010).

Conformation is an important trait, and it serves as a basis for selection of cows in breeding herds while accounting for the fact that cattle conformation is associated with production and nonproduction traits, and thus with production efficiency (Zavadilova and Stipkova, 2012). The relationship of conformation traits with milk production traits might be different between breeds, which could have implications for the use of conformation traits in different dairy cattle breeding programmes (Haas et al., 2007).

Various studies have been conducted to quantify the importance and the impact of type traits on production and longevity traits in dairy cattle (Larroque and Ducrocq, 2001; Harder et al., 2004). Selection in commercial herds of dairy cattle is based almost exclusively on production traits, especially those directly related to the increase in income from dairy farming (volume, fat and protein of milk), while improved milk composition may receive higher premiums depending on the region (Cardoso et al., 2004; Boligon et al., 2005). Longevity is a trait of high importance in breeding programs (Vukasinovic et al., 2002). The drive to increase milk yield in the modern dairy cow has resulted in declining longevity. Holstein is one of the excellent milk-producing economic livestock. Thus, lactation traits maintain main target in breeding selection of improvement (Carlen et al., 2004). In recent decades, dairy cattle breeding has become an increasingly international business and a substantial exchange of Holstein semen has taken place worldwide (Powell and Sieber, 1994). The Holstein dairy cow, has a high genetic potential for milk production. However, importation of Holstein cows into regions that cannot provide the necessary nutritional, health, and physical environments to support their genetic potential for production leads to poor health, milk production, and reproduction (compounded with the already low genetic merit of the breed for this trait) resulting in underperformance and long-term inefficiency of the production system (Evans et al., 2006).

The aim of this study was to investigate the influence of genotype and environment on improvement of selected traits in Lithuanian Black and White cows.

Material and methods

The evaluation of milk production and composition, conformation and reproduction traits of cows was carried out by the data of Lithuanian Black-and-White cattle improvement association, the Centre of State Business Development and Information at the Laboratory of Genetic evaluation and selection of animals of the Lithuanian University of Health Sciences.

The average percentage of Holstein genes in cow's genotype has been estimated according to records of cows with complete 3 ancestor's generations pedigree information (n= 52432).

The productivity level of the evaluated herds was estimated according to the average of the individual milk production of cow's during 305 days of lactation and was in agreement with distribution according to a productivity of Black and White cattle population in Lithuania (Annual report of milk recording No. 80). The production level of class 1 was till 6500 kg (n =7158); class 2– from 6500 to 7999 kg (n=34114); class 3 – more than 8000 kg of milk (n=11160).

For the analysis a PostgreSQL data basis was created (at the Laboratory of Genetic evaluation and selection of animals of the Lithuanian University of Health Sciences) and the data of cows' - pedigree, exterior, reproduction and milk production were evaluated.

Investigated 19 conformation traits of 52432 cows (accounted for 49.78 % from total amount of controlled Black and White cattle population in Lithuania, Annual report of milk recording No. 80), evaluated according to the recommendations of international organizations ICAR and INTERBULL, European council directives 77/504, 86/130,87/328, 94/515 and The State Animal Breeding Supervision Service founded under the Ministry of Agriculture of the Republic of Lithuania (Order No. 1A-15, 2011 05 26.) Optimal scores of Lithuanian Black and White cow's conformation traits are given in the table 1 (Saikevicius and Juozaitiene, 2004).

Table 1. **Optimal scores of cow's conformation traits**

Optimal scores of body assessment traits		Optimal scores of extremities assessment traits		Optimal scores of udder assessment traits	
Height	9	Rear leg set angle	5	Udder attachment	9
Stoutness	8	Rear leg form	6	Udder height	9
Body depth	8	Heel joint	8	Udder cleft	9
Chest width	7	Hoof height	8	Udder depth	9
Dairy type	8	Hoof tarsus angle	7	Teat placement	6
Rump width	7			Teat thickness	5
Rump angle	5			Teat length	6

Statistical analysis (mean ±standard error, Pearson's correlation and linear regression) was calculated by using the SPSS 17 package. Student's t-test was used for assessing the statistical significance of the difference between means of two samples. The results were considered as significant at $P \leq 0.05$, $P < 0.01$ and $P < 0.001$.

Results and discussion

Degree of Holstein genes

The average proportion of Holstein genes in Lithuanian Black and White cows' genotype was 66.25±0.081% (2 % of cows has till 25 % of Holstein breed genes, 5% of cows – from 25 - 37.5 %, 10 % of cows from –37.5 - 50 %, 18 % of cows from– 50 % - 62.50%, 25 % of cows – 62.50 - 75 %, 27% of cows –75 - 87.5 % and 13 % of cows – 87.5 - 100 %). The increase of Holstein genes **(y)** in cows' genotype by 12.5% was associated with statistically significant growth ($P < 0.001$) of milk yield (x) by linear regression equation: $y = 139.72x + 5331.2$ ($R^2=0.852$); milk fat kg: $y = 2.1429x + 96.357$ ($R^2 = 0.7305$) and protein kg: $y = 2.3095x + 97.357$ ($R^2 = 0.7685$), but has a tendency to decrease for a longevity of cows in months: $y = -1.6745x+38.513$ ($R^2=0.6926$).

Analysis showed 16.1 % higher an average proportion of Holstein genes in Lithuanian Black and White cows of herd productivity class 3 (71.06±0.16%) compared with the lowest Holstein breed degree (61.202±0.218%) in the herds of class 1 ($P < 0.001$). Evaluated cows were on average 2.66±0.007 lactation, in the herds of class 3 (3.12±0.02 lactation), 34% more compared with the class 1 ($P < 0.001$). The average milk fat % of cows varied from 4.29±0.01% (herd class 3) to 4.34±0.01% (herd class 1; $P<0.001$); milk protein % – from 3.29±0.00 % (herd class 1and 3) to 3.32±0.00 % (herd class 2).

Production level and traits

The analysis (figure 1) showed low positive, statistically significant coefficient of correlation between milk and fat (positive in a class 1, r= 0.024) between milk and protein (positive in the class 1, r=0.043, to negative in the class 3, r=-0.163), between milk and longevity (positive, from r=0.033 in the class 1, to r=0.056 in the class 2), between fat and protein (from r=0.254 in the class 3 to r=0.300 in the class 2), between fat and longevity (from r=0.060 in the class 2, to r=0.097 in the class 3), between protein and longevity (from positive r=0.015 in the class 1, to negative r=-0.045 in the class 3).

The growth of the productivity level of herds was statistically significantly associated with a negative phenotypic correlation of cow's milk yield with fat (class 2), milk yield and protein (class 3), protein and longevity (class 3), (P < 0.001).

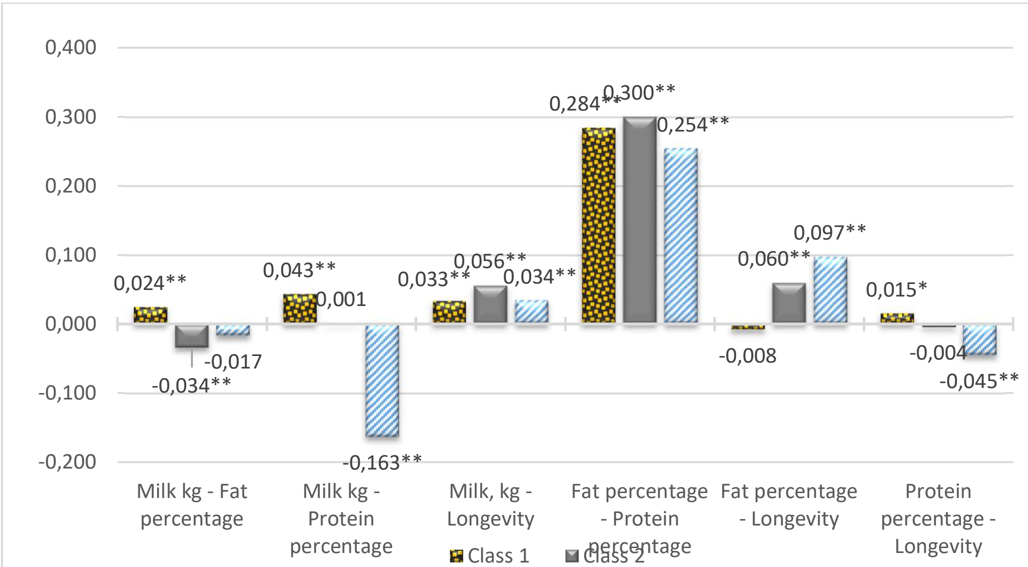

Fig. 1. **The phenotypic correlations within investigated traits, according to the 3 classes of production level**
* P < 0.05, ** P < 0.01 *** P < 0.001.

The superiority of Holsteins for milk production has contributed to a growing global domination of the Holstein breed over time. Holsteins tend to have the lowest milk protein percentage, at between 3.15 and 3.25 percentage protein, of all the traditional European breeds of economic importance (Robinson, 2000). During recent years, however, milk pricing in most markets has placed greater emphasis on the solids in milk rather than fluid, which resulted in the Holstein breed having less of a competitive advantage compared with other breeds (Heins et al., 2006).

Fertility traits

Selection for higher yields of dairy cattle has led to a decline in fertility due to unfavourable genetic correlations between yield and fertility (Washburn et al., 2002; Pryce et al., 2004). The same tendency is noted in this study.

Crossbreeding Holsteins with other breeds has been an option to help minimize the decline of health and fertility (Weigel and Barlass, 2003; Heins et al., 2006).

A decline in fertility reduces the percentage of cows in their peak production period, which reduces milk yield in herds. Lower fertility increases insemination costs and leads to increased involuntary culling (USDA, 2007; Turkyilmaz, 2005). Norman et al. (2007) documented that unsatisfactory reproductive performance remains a primary reason for culling a cows.

Table 2. **The reproduction traits of cows**

Herd class	Insemination times for a pregnancy	Service-period after calving, days	Calving interval, days
1 ^{a}	1.46±0.05 $^{***\ b;\ c;\ d}$	82.8±2.03 $^{***c;\ d}$	363±1.92 $^{***\ b;\ c;\ d}$
2 ^{b}	1.70±0.04 $^{***\ a;\ c;\ d}$	87.9±1.97 $^{***\ c;\ d}$	389±2.$^{11\ ***\ a;\ c;\ d}$
3 ^{c}	1.97±0.02 $^{***\ a;\ b;\ d}$	116.7±2.01 $^{***\ a;\ b}$	401±1.77 $^{***\ a;\ b;\ d}$
4 ^{d}	2.31±0.04 $^{***\ a;\ b;\ c}$	120.9±1.74 01 $^{***a;\ b}$	409±2.01 $^{***\ a;\ b;\ **c}$
Correlation of milk production classes with reproduction traits of cows			
1	0.29**	0.33***	0.31***
2	0.31***	0.37***	0.36***
3	0.33***	0.38***	0.39***
4	0.45***	0.40***	0.42***
a; b; c - means with different superscript letters indicate significant differences; ** Means within a column with a different superscript differ at P < 0.001; *** Means within row's with a different superscript differ at P < 0.001			

Lof with other researchers (2007) estimated that low-yielding herds had greater (P < 0.001) odds for culling attributed to reproductive problems than high-yielding herds. Dairy producers in Ireland and New Zealand have expressed concern regarding the declining fertility of cows with increased Holstein genes. In Ireland, Dillion and Buckley (1998) reported that high genetic merit cows had an overall infertililty rate of 25% vs. 6% for medium genetic merit cows. Harris and Winkelman (2000) and Verkerk with other researchers (2000) reported significant differences between cows of New Zealand origin and North American origin for conception rate, services per conception, and days to first service. This could be a consequence of changes in farm management systems, genotypic changes, or both.

Our analysis showed (Table 2) that a higher average of Holstein breed genes in herds with a higher productivity level increased times of insemination, prolonged service and calving interval (P<0.001), showing that with cows producing peak yields, it is difficult to achieve a 365 days calving interval, as such cows may not return to a positive energy balance until 15-18 weeks post-partum and fertility is likely to be impaired. The highest positive correlations of Holstein breed degree with reproduction traits of cows was estimated in herds with a highest productivity level (r = 0.40 -0.45, P < 0.001).

In the herds with different production level, farmers or owners of agricultural companies for increase of output are using various technologies, breeding, nutrition and management methods. Different farmers attribute different values to inputs and outputs. In this context, type traits have a direct influence on the management of cows and are related to the profitability of the herd (Darili et al., 2008; Jeretina et al., 2013). The long-term competitive, profitable milk-production can only be achieved by the reduction of production costs and animal diseases. These costs have become very important risk factors of herd profitability. Studies carried out in intensive dairy units showed that lameness was responsible for the third largest economic losses after mastitis and reproductive disorders, and the largest part of losses resulted from the returns foregone, that is, the diminished income due to reduced production (Ozsvari, 2017).

Conformation traits

As presented in the table 3, the phenotypic scores for body depth, rump width were approximately 1.5 points lower than the optimal score. The mean phenotypic score for height was 2.5 points lower than the optimal score. Stoutness, chest width, in the second class was close to the ideal score. The scores of rump angle were close to the ideal score almost in all classes of herds.

Table 3. **The range of the average score of cows evaluated by body assessment traits compared to the optimal score of cow's assessment system**

Herd class	Body assessment traits						
	Height	Stoutness	Body depth	Chest width	Dairy type	Rump width	Rump angle
1 ^{a}	2.86 ±0.026 $^{***b; c}$	1.1±0.028 $^{***b; c}$	1.74±0.011 $^{***b; c}$	0.77±0.013 $^{***b; c}$	1.28±0.016 $^{***b; c}$	1.61±0.01 $^{*b; ***c}$	0.04±0.011 $^{*b; ***c}$
2 ^{b}	2.63±0.016 $^{***a; c}$	0.69±0.016 $^{***a; c}$	1.66±0.007 $^{***a; c}$	0.7±0.008 $^{***a; c}$	1.16±0.01 $^{***a; c}$	1.58±0.006 $^{*a; ***c}$	0.01±0.007 $^{*a; ***c}$
3 ^{c}	1.43±0.017 $^{***a; b}$	1.64±0.015 $^{***a; b}$	1.62±0.007 $^{***a; b}$	0.06±0.009 $^{***a; b}$	0.06±0.01 $^{***a; b}$	2.56±0.006 $^{***a; b}$	2.02±0.007 $^{***a; b}$
Extremities assessment traits							
	Rear leg set angle	Rear leg form	Heel joint	Hoof height	Hoof tarsus angle		
1 ^{a}	- 0.17±0.011 ^{*b}	1.46±0.012 ^{***c}	1.72±0.018 ^{**c}	2.96±0.013 ^{**c}	2.24±0.011		
2 ^{b}	-0.2±0.007 $^{*a; c}$	1.45±0.007 ^{***c}	1.68± 0.012	2.95± 0.009 ^{**c}	2.25±0.007		
3 ^{c}	-0.18± 0.007 ^{*b}	1.41±0.008 $^{***a; b}$	1.66± 0.012 ^{**a}	2.92± 0.009 $^{**a; b}$	2.24± 0.007		
Udder assessment traits							
	Udder attachment	Udder height	Udder cleft	Udder depth	Teat placement	Teat length	Teat thickness
1 ^{a}	3.34±0.016	2.49±0.02 $^{***b; c;}$	2.07±0.02	3.29±0.018 $^{**b; ***c}$	1.10± .012 ^{***c}	0.66±0.013 ^{**c}	2.55±0.005 $^{***b; c}$
2 ^{b}	3.34±0.01	2.38±0.013 $^{***a; c}$	2.05±0.013	3.35±0.011 $^{**a; ***c}$	1.08±0.007 ^{***c}	0.65±0.008 ^{**c}	2.53±0.003 $^{***a; c}$
3 ^{c}	3.36±0.011	2.26±0.013 $^{***a; b}$	2.03±0.013	3.47±0.011 $^{***a; b}$	1.04±0.08 $^{***a; b}$	0.62±0.008 $^{**a; b}$	2.51±0.003 $^{***a; b}$
a; b; c - means with different superscript letters indicate significant differences; * P < 0.05, ** P < 0.01 *** P < 0.001							

Assessments on European dairy farms have shown that the prevalence of hock lesions is as high as 100% on some farms (Kielland et al., 2009; Brenninkmeyer et al., 2013) and variation is from 22 to 61%, depending on the characteristics of the housing system and season (Rutherford et al., 2008). In Lithuania every year an average of 4 % of the cows (of all culled cows) are culled for feet and 14 - 15 % (of all culled cows) for udder diseases (Annual report of milk recording No. 75, 76, 77, 80).

In terms of the extremities traits, the scores were in the range of the ideal scores. Rear leg set angle were more than the ideal score approximately 0.2 point. Rear leg form, heel joint approximately 1.5 points, hoof height – 2.94, hoof tarsus angle - 2.23 points lower than the optimal score.

Amory with co-authors (2008) found that higher yielding cows were more likely to become clinically lame. Locomotion disease recording programs are not widely implemented, feet and leg conformation traits are most commonly used as indicator traits. However, selection for these traits alone has not reduced lameness problems (Bielfeldt et al., 2005).

Teat placement was more than 1 point below the ideal score in all classes showing, that teats are not in the middle, but a little bit out of the udder quarter placed teats. In all herd classes by production level score for teat length was close to the optimal score. Scores for udder depth and udder cleft were lower 2 – 3 points below the ideal scores of 9, respectively.

Udder depth is the most important physical trait of the udder. High-yielding cows have deeper udders (Norman et al., 1988), and this could cause sanitary problems, which influence the longevity of the animal (Larroque and Ducrocq, 1999; Perez-Cabal and Alenda, 2002). Tsuruta et al. (2005) found that more capacious and better attached udders, shorter teats, smaller body size, straighter legs, steeper foot angle and higher overall conformation scores were consistently related to increased herd life. Schneider et al. (2003) found that udder and height had the strongest relationship with functional herd life, compared with other structural body traits.

As it was presented in table 3, in herds with a highest productivity level and highest Holstein breed genes phenotypic scores for conformation traits indicates deeper body depth, wider and deeper chest width, but narrower rump width, weaker heels, intermediate height, lower foot angle, deeper and weaker attached udders.

Feet and leg diseases are a persistent, non - decreasing problem in modern intensive dairy production. Disorders of the hoof, sometimes also called claw disorders, are major reasons for a reduced lifespan (Cramer et al., 2009), impaired well-being, and inferior productivity (Sogstad et al., 2006). Environmental factors also influence feet and leg traits. Diet, housing, and general management all affect the health of feet and legs (Greenough and Weaver, 1997).

Conclusions

1. Genotype of cows had a statistically significant impact on productivity and longevity traits of Lithuanian Black and White cows. The increase of Holstein genes in genotype was associated with the growth of milk yield, fat and protein production (R^2=0.7305-0.852), but had a tendency to decrease a longevity of cows (R^2=0.6926), ($P < 0.001$).

2. The growth of the productivity level of herds was statistically significantly associated with a negative phenotypic correlation of cow's milk yield with fat, milk yield and protein, protein with longevity, reflecting an unfavourable effect on milk composition and lifespan, indicating that the increase in production should be viewed with concern ($P < 0.001$).

3. Reproductive traits of cows were influenced by genotype and environmental - a higher degree of Holstein genes related with increase times of insemination, prolonged service period and calving interval of cows ($P < 0.001$); the highest positive correlations of Holstein breed degree with reproduction traits of cows was estimated in herds with a highest productivity level ($r = 0.40$ -0.45, $P < 0.001$).

4. The average amount of Holstein genes of cows evaluated by an optimal score based on conformation traits, showed that cows with a higher amount of Holstein genes with a higher productivity level are taller, more capacious, with deeper chest width, straighter leg form and leg set angle, with moderately attached udder, udder cleft and teat length.

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