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Genetic markers for energy assessment in cattle

Suma 1,Sravani 2

Abstract

The purpose of this study was to examine how intensive milk production technology (cold heifer rearing, early heifer insemination, high daily operating loads, etc.) affects the bioenergetic parameters of high-yielding Holstein breed cows by studying polymorphism of allelic variants of somatotropin GH genes and pituitary-specific transcription factor PIT-1. The PCR method was used to identify the cows' genotypes. The DNA in the blood was analyzed at a genetics lab. "Chelex-100" resin was used for the isolation of genomic DNA. The "Tertsyk" amplifier was used to carry out the reaction. Net maintenance energy (in MJ per day), net milk energy (in MJ per day), total net energy consumption (in MJ per day), energy index value (in % of energy released from milk), productivity index (in kilograms of 4% milk per 1 MJ), net energy consumption per 1 MJ of milk (in MJ), and energy released with milk per 1 kg of metabolic mass (in MJ) were all used for the energy assessment of young cows. The LL genotype of the GH gene, the AB genotype of the pituitary-specific transcription factor PIT-1, and the LL/AB and LL/BB paired genotypes all result in optimal energy output in cows. Compared to animals of the LV, BB, and LV/BB genotypes, these animals consistently had stronger bioenergetic markers during both the first and second lactational phases. Bioenergetic indices favor cows of the LL/AB genotype over those of the LV/BB genotype, however this advantage is much less during the first lactation period (3.9-15.2%) than it is during the second (1.8-7.4%). Genotype AB cows had higher bioenergetic characteristics than genotype BB cows did for the pituitary-specific transcription factor PIT-1. The larger lactotropic function of the L and A alleles, which results from a greater complementary influence on the functioning of the alleles of the linked genes in the complex genotype, explains the difference in bioenergetic parameters. The analysis of variance of one-factor complexes supported this finding, showing that genotypes had a greater effect on bioenergetic parameters during the first phase of breastfeeding compared to the second. However, regardless of lactation duration, the level of the paired genotype's impact on the GH and PIT-1 genes was consistently substantial, ranging from 8.9 to 20.9% (P 0.01-0.001). It will be interesting to see how polymorphisms in the GH and PIT-1 genes affect the outward appearance and internal make-up of various types of cows in the future.

Key words: Polymorphism in GH and PIT-1 genes, pure support energy, pure milk energy, energy and productivity index.

1. Introduction

For the development of dairy farming requires new methods for assessing the biological characteristics of the animal body in terms of intensive technology of milk production at high operating loads on the body (VanRaden & Sullivan, 2010; Mylostyvyi et al., 2019; Trakovická et al., 2019). One such method is the assessment of energy metabolism in dairy cows, in particular the determination of energy expenditure for live weight maintenance and milk synthesis (Petrenko et al., 2005). Some scientists have established the influence of the type of constitution on the energy performance of cows (Chernenko, 2012; Chernenko & Chernenko, 2018) and ecogenesis (Denysyuk, 2009). Studies of the influence of the genotype of cows on thegenes of somatotropin GH and pituitary-specific transcription factor PIT-1 have not been conducted before,which determines the relevance and scientific novelty of this problem.

2. Materials and methods

The research was conducted at PJSC “Agro-Soyuz” of Dnipropetrovsk region. The sample included one-year-old Holstein cows. The source material was DNA samples isolated from the blood of experimental animals. The PCR method was used to determine the polymorphism of marker genes (Burkat et al., 2009). The research was conducted under the guidance of specialists from the Laboratory of Genetic Control of the Institute of Pig Breeding and Agroindustrial Production of NAASU, Poltava. The method was used to conduct energy assessment of first-born cows (Petrenko et al., 2005). Biometric processing of the material was performed using MS Excel 2010.

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Results and discussion

Results

While analyzing the collected scientific data (Table 1), it can be noted that according to the results of energy evaluation of Holstein cows of different genotypes by the GH gene for the first lactation, animals of the LL genotype were the best. Compared to their peers of the LV genotype, they had per day higher indicators of net support energy spent on live weight maintenance and net milk energy spent on milk production, respectively by 1.9 MJ (3.8 %) atP < 0.01 and 7.5 MJ (9.1 %) for P < 0.001; higher total net energy consumption by 9.6 MJ (7.2 %) for P < 0.001. In these animals, the energy and productivity indices were higher by 1.3 % (P < 0.01) and 0.01 kg/MJ (P < 0.01), respectively. They had a lower net energy consumption per1 MJ of milk by 0.03 MJ (1.8 %) at P < 0.01 and they released slightly more energy with milk per 1 kg of metabolic mass by 0.03 MJ (5.1 %) at P < 0.001.

Table 1

Energy evaluation of Holstein cows of different genotypes by gene GH, $\bar{X} \pm S_{\bar{X}}$

Feature	Genotype of cows by growth hormone gene GH			
	LL (n = 148)	LV (n = 20)	LL (n = 102)	LV (n = 13)
	I lactation		II lactation	
Net support energy, MJ per day	52.3 ± 0.31**	50.4 ± 0.69	53.1 ± 0.31	52.1 ± 0.87
Pure energy of milk, MJ per day	89.6 ± 0.81***	82.1 ± 1.64	112.6 ± 1.15**	102.8 ± 2.71
Total net energy consumption, MJ per day	142.1 ±1.08***	132.5 ± 2.22	165.7 ± 1.41**	155.1 ± 3.42
Energy index (share of energy released with milk), %	63.2 ± 0.14**	61.9 ± 0.31	67.9 ± 0.15***	66.3 ± 0.41
Productive index, kg MCJ (4 %) of milk per 1 MJ	0.21 ± 0.005**	0.20 ± 0.001	0.22 ± 0.001***	0.22 ± 0.002
Net energy consumption per 1 MJ of milk, MJ	1.59 ± 0.003**	1.62 ± 0.008	1.47 ± 0.003***	1.51 ± 0.009
Energy with milk per 1 kg of metabolic mass, MJ is allocated	0.68 ± 0.004***	0.65 ± 0.007	0.85 ± 0.006***	0.79 ± 0.014

Note: * – P<0,05; ** – P<0.01*** – P<0.001 comparing with the genotype LV

The results of the energy evaluation of Holstein cows of different genotypes by the GH gene for the second lactation (see Table 1) show that animals of the LL genotype have a slightly higher indicator of net maintenance energy per live weight of 1.0 MJ per day (1.8 %) and net energy for production milk at 9.8 MJ per day (9.5 %) for P < 0.01; higher total net energy consumption by 10.6 MJ (6.8 %) at P < 0.01.

Furthermore, these animals had higher values of energy and productivity indices by 1.6 % (P < 0.001) and 0.01 kg/MJ (P < 0.001), respectively, but lower net energy consumption per 1 MJ of milk by 0.03 MJ (2.3 %) at P > 0.999 and more released energy with milk per 1 kg of metabolic mass at 0.06 MJ (7.4 %) at P < 0.001.

Having conducted an energy evaluation of Holstein cowsof different genotypes by the PIT-1 gene during the first lactation, it was found that animals of both genotypes didnot have significant differences in terms of net maintenance energy spent on live weight maintenance (Table 2).

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Table 2

Energy evaluation of Holstein cows of different genotypes by gene PIT-1, $\bar{X} \pm S_{\bar{X}}$

Feature	Genotype of cows by growth hormone gene PIT-1			
	AB (n = 53)	BB (n=113)	AB (n = 37)	BB (n = 78)
	I Lactation		II Lactation	
Net support energy, MJ per day	52.2 ± 0.45	52.1 ± 0.35	53.1 ± 0.51	52.9 ± 0.36
Pure energy of milk, MJ per day	92.7 ± 1.19***	87.1 ± 0.93	115.4 ± 1.68**	109.7 ± 1.34
Total net energy consumption, MJ per day	144.9 ± 1.57**	139.1 ± 1.25	168.4 ± 2.11*	162.6 ± 1.64
Energy index (share of energy released with milk), %	63.9 ± 0.19***	62.4 ± 0.14	68.5 ± 0.19***	67.4 ± 0.17
Productive index, kg MCJ (4 %) of milk per 1 MJ	0.21 ± 0.002*	0.20 ± 0.001	0.22 ± 0.001***	0.21 ± 0.001
Net energy consumption per 1 MJ of milk, MJ	1.57 ± 0.005***	1.61 ± 0.004	1.46 ± 0.004***	1.49 ± 0.003
Energy with milk per 1 kg of metabolic mass, MJ is allocated	0.71 ± 0.006***	0.67 ± 0.003	0.87 ± 0.008***	0.83 ± 0.007

However, in one year old cows of the AB genotype, the net energy consumption of milk was higher by 5.6 MJ (6.4 %) at P < 0.001 and the total net energy consumption by 5.8 MJ (4.1 %) at P < 0.01; energy and productivity indices, respectively, by 1.5% for P < 0.001 and 0.01 kg/MJ for P < 0.05, but lower net energy consumption per 1 MJ of milk by 0.04 MJ (2.7 %) for P < 0.001. They released more energy with milk per 1 kg of metabolic mass at 0.04 MJ (6.5 %) at P < 0.001.

Animals of different genotypes in the PIT-1 gene during the second lactation did not differ much in terms of net maintenance energy spent on live weight maintenance.

However, one year old cows of genotype AB compared to peers of genotype BB had higher costs for pure energy of milk by 5.7 MJ (5.2 %) at P < 0.01 and total net energy consumption by 5.8 MJ per day (3.5 %) at P < 0.05; energy and productivity indices, respectively, by 1.1 % for P < 0.001 and 0.01 kg/MJ (6 %) for P < 0.001. In this group of animals, the net energy expenditure per 1 MJ of milk was lower by 0.04 MJ (2.7 %) at P > 0.999 and they released more energy with milk per 1 kg of metabolic mass by 0.04 MJ (5.1 %) at P < 0.001.

Having conducted an energy assessment of Holstein cows of complex genotypes during the first lactation, it was found that the best traits are characterized by individuals of the LL/AB genotype, which compared to the LV/BB genotype had a higher net maintenance energy of 2.2 MJ per day (3.9 %) at P < 0.05 and net milk energy by 12.3 MJ (15.2 %) at P < 0.001; higher total net energy consumption by 14.2 MJ per day (10.9 %) at P < 0.001; higher energy and productivity indices, respectively, by 2.4 % for P < 0.001 and 0.01 kg/MJ (3.9 %) for P < 0.001. These animals have a lower net energy expenditure per 1 MJ of milk by 0.06 MJ (3.7 %) at P < 0.001 and more emit energy with milk per 1 kg of metabolic mass by 0.07 MJ (10.9 %) at P < 0.001 (Table 3).

Table 3

Energy characteristics of Holstein cows of complex genotypes during the first lactation, $\bar{X} \pm S_{\bar{x}}$

Feature	Cows Genotype		
	LL/AB, n = 49	LL/BB, n = 95	LV/BB, n = 17
Net support energy, MJ per day	52.2 ± 0.49*	52.3 ± 0.36*	50.2 ± 0.76
Pure energy of milk, MJ per day	92.7 ± 1.29***	88.1 ± 1.03***	80.5 ± 1.59
Total net energy consumption, MJ per day	144.9 ± 1.71***	140.4 ± 1,35***	130.7 ± 2.27
Energy index (share of energy released with milk), %	63.9 ± 0.22***	62.7 ± 0.16***	61.6 ± 0.26
Productive index, kg MCJ (4 %) of milk per 1 MJ	0.21 ± 0.001***	0.22 ± 0.002***	0.19 ± 0.001
Net energy consumption per 1 MJ of milk, MJ	1.56 ± 0.005***	1.61 ± 0.004***	1.63 ± 0.006
Energy with milk per 1 kg of metabolic mass, MJ is allocated	0.71 ± 0.006***	0.71 ± 0.006***	0.64 ± 0.007

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One year old cows of the LL/BB genotype took an intermediate position in all bioenergetic traits, but when compared with peers of the LV/BB genotype, there is a significant and probable difference in favor of individuals in this group.

In Holstein cows of complex genotypes during the second lactation, significant differences in net maintenance energy spent on live weight maintenance were not found. However, peers of the LL/AB genotype compared to their peers of the LV/BB genotype showed higher milk energy

expenditures by 14.6 MJ per day (14.5 %) at P < 0.001; higher total net energy consumption by 15.8 MJ

per day (10.4 %) at P < 0.001; higher energy and productivity indi- ces, respectively, by 2.5 % for P < 0.001

and 0.02 kg/MJ(7.1 %) for P < 0.001. Animals in this

group have lower net energy expenditure per 1 MJ of milk by 0.05 MJ (3.6 %)P < 0.001 and more emit energy with milk per 1 kg of meta- bolic mass by 0.09 MJ (11.9 %) at P < 0.001 (Table 4).**Table 4**

Energy characteristics of Holstein cows of complex genotypes during the second lactation, $X \pm S_x$

Feature	Cows genotype		
	LL/AB, n = 34	LL/BB, n = 66	LV/BB, n = 11
Net support energy, MJ per day	52.9 ± 0.55	53.1 ± 0.39	51.7 ± 0.99
Pure energy of milk, MJ per day	115.5 ± 1.82***	111.3 ± 1.45**	100.9 ± 2.81
Total net energy consumption, MJ per day	168.4 ± 2.31***	164.4 ± 1.78**	152.6 ± 3.59
Energy index (share of energy released with milk), %	68.5 ± 0.21***	67.6 ± 0.18**	66.1 ± 0.43
Productive index, kg MCJ (4 %) of milk per 1 MJ	0.23 ± 0.001***	0.22 ± 0.002**	0.21 ± 0.002
Net energy consumption per 1 MJ of milk, MJ	1.46 ± 0.004***	1.48 ± 0.004**	1.51 ± 0.011
Energy with milk per 1 kg of metabolic mass, MJ is allocated	0.87 ± 0.008***	0.84 ± 0.007***	0.78 ± 0.015

In its turn, the animals of the LL/BB genotype were slightly inferior to the peers of the LL/AB genotype in terms of the value of the studied traits, but in comparison with the animals of the LV/BB genotype a significant difference in net milk energy was found by 10.4 MJ per day (10.3 %) at P < 0.01 , total net energy consumption by 11.8 MJ per day (7.7 %) at P <0.01; the energy and productivity indices were higher, respectively, by 1.5 % at P < 0.01 and 0.01 kg/MJ (4.7 %) at P < 0.01. The cows of this group had slightly lower net energy consumption per 1 MJ of milk by 0.03 MJ (2.2%) at P < 0.01 and more energy was released from milk per 1 kg of metabolic mass by 0.06 MJ (7.2 %) at P < 0.001.The share of genotype influence on bioenergetic parame-ters of cows during the first lactation is presented in table. 5.Thus, the share of the genotype of the GH growth hor-mone genotype on net support energy was in the range of 8.0 % at P < 0.01, on pure milk energy 7.8 % at P < 0.01, total net energy expenditure 5.5 % at P < 0.05, energy and productivity indices, respectively 18.4 and 18.3 % forP < 0.001, for net energy consumption per 1 MJ of milk 17.8 % for P < 0.001, for energy released with milk per 1 kgof metabolic mass 19.3 % for P < 0.001.

Table 5

The share of genotype influence on bioenergetic parameters of cows during the first lactation, η^2_x,%

Feature	Genotype		
	GH	PIT-1	GH/PIT-1
Pure support energy	8.0**	6.9**	11.9***
Pure energy of milk	7.8**	7.1***	12.2***
Total net energy consumption	5.5*	4.2**	9.4***
Energy index (share of energy released with milk), %	18.4***	18.5***	20.4***
Productive index, kg MCJ (4 %) of milk per 1 MJ	18.3***	18.2***	20.5***
Net energy consumption per 1 MJ of milk	17.8***	17.9***	20.1***
Energy with milk per 1 kg of metabolic mass is released	19.3***	19.1***	20.8***

Note: * – P < 0.05; ** – P < 0.01; *** – P < 0.001

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The share of the influence of the genotype by the RIT-1 gene on net energy of support was 6.9 % for P < 0.01, on pure milk energy 7.1 % for P < 0.001, total net energy con- sumption 4.2 % for P < 0.01, energy and productivity indi- ces, respectively 18.5 and 18.2 % for P < 0.001, for net energy consumption per 1 MJ of milk 17.9 % for P < 0.001, for energy released with milk per 1 kg of metabolic mass 19.1 % for P < 0.001. 1.

According to the complex genotype GH/PIT-1, the share of impact on net energy of support was in the range of 11.9 % for P < 0.001, for pure energy of milk 12.2 % forP < 0.001, total net energy consumption 9.4 % for P <0.001, energy and productivity indices, respectively 20.4 and 20.5 % for P < 0.001, for net energy consumption per 1MJ of milk 20.1 % for P < 0.001, for energy released with milk per 1 kg of metabolic mass 20.8 % for P < 0.001.

The share of genotype influence on bioenergetic parame-ters of cows during the second lactation is presented in table 6. Thus, the share of the influence of the genotype for the GH growth hormone gene on all indicators of energy evaluation of cows during the second lactation was slightly less than during the first lactation and was: net maintenance energy was 6.1 % at P < 0.01; for net energy of milk 6.9 % at P < 0.01; for total net energy consumption 5.6 % atP < 0.05; on energy and productivity indices, respectively 10.1 and 10.0 % for P < 0.05; for net energy consumptionper 1 MJ of milk 10.1 % at P < 0.001; on the released ener- gy with milk per 1 kg of metabolic mass 9.8 % at P < 0.001.

Table 6

The share of genotype influence on bioenergetic parameters of cows during the second lactation, η^2_x,%

Feature	Genotype		
	GH	PIT-1	GH/PIT-1
Pure support energy	6.1**	4.9*	11.1**
Pure energy of milk	6.9**	5.2*	11.5**
Total net energy consumption	5.6*	3.7*	8.9**
Energy index (share of energy released with milk), %	10.1***	11.7***	20.7***
Productive index, kg MCJ (4 %) of milk per 1 MJ	10.0***	11.3***	20.9***
Net energy consumption per 1 MJ of milk	10.1***	11.7***	20.7***
Energy with milk per 1 kg of metabolic mass is released	9.8***	11.6***	20.2***

The share of the influence of the RIT-1 gene genotype on the studied parameters during the second lactation was also smaller than during the first lactation period and was:on the net support energy 4.9 % at P < 0.05; for pure energy of milk 5.2 % at P < 0.05; for total net energy consumption 3.7 % at P < 0.05; on energy and productivity indices, re- spectively 11.7 and 11.3 % for P < 0.001; for net energy consumption per 1 MJ of milk 11.7 % at P < 0.001; on the released energy with milk per 1 kg of metabolic mass 11.6 % at P < 0.001.

According to the complex genotype GH/PIT-1 for the second lactation, the share of influence on the indicators of energy evaluation of cows remained almost unchanged and was: on net energy support 11.1 % at P < 0.01; for net ener- gy of milk 11.5 % at P < 0.01; for total net energy consump-tion 8.9 % at P < 0.01; on energy and productivity indices, respectively 20.7 and 20.9 % for P < 0.001; for net energy consumption per 1 MJ of milk 20.7 % at P < 0.001; on the released energy with milk per 1 kg of metabolic mass of 20.2 % at P < 0.001, which indicates a general positive en- ergy balance in the body of these animals.

Discussion

The analysis of variance of one-factor complexes re-vealed the peculiarities of the influence of polymorphism in the GH and PIT-1 genes on the bioenergetic parameters of cows in the context of the first two lactations. In particular, during the first and second periods of lactation, each geno- type of the GH and PIT-1 gene has a different effect on these traits - a stronger effect in the first lactation than in the second. Perhaps this is due to even more intensively grow- ing first-born cows with their greater dependence on the function of the

growth hormone GH gene and pituitary-

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specific transcription factor PIT-1 (Zhao et al., 2004). How- ever, the strength of the influence of the paired genotype on the gene GH and PIT-1 remains equally high regardless of the lactation period. This is the result of greater complemen-tary

functioning of associated genes and their alleles in the complex genotype (Shariflou et al., 2000; Akyuz et al., 2015). Our data coincide with the results of research by other scientists (Krupin & Shakirov, 2019), who evaluated the energy performance of cows depending on the polymor- phism in several genes, including the GH and PIT-1 genes.

3. Conclusions

Bioenergetic parameters of highly productive cows with their intensive use depend on the polymorphism in the genesGH and PIT-1. In cows with LL genotype by GH gene and cows with AB genotype by pituitary-specific transcription factor PIT-1 gene, as well as by polymorphism in both genes, i.e. paired LL/AB and LL/BB genotypes, bioenerget- ic parameters for the first and second lactation periods were higher than their peers of LV, BB and LV/BB genotypes by 2.0–15.2 % with a reliable result for most traits ($P < 0.01$– 0.001). The effect of polymorphism in the GH and PIT-1 genes was stronger in the first period of lactation than in the second. However, polymorphism of the paired genotype for these genes has always had a more pronounced effect on the signs of energy evaluation of cows. The share of its influ- ence, according to the results of analysis of variance, ranged from 8.9 to 20.9 % ($P < 0.01$–0.001).

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