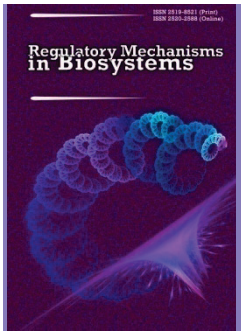

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Characteristics of kappa-casein gene polymorphism in cows of Swiss breed and their productive qualities at a large dairy

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Kappa-casein is a fraction of the main milk protein, which determines the technological properties of milk and the quality of dairy products, especially cheese and fermented milk products. The study tested the distribution of kappa-casein gene genotype polymorphism (CSN3) in mothers and daughters of the Swiss breed cows, taking into account their milk productivity qualities. The study was performed on 111 cows of the Swiss breed on a large dairy. The observation group I included 51 cow-mothers of the Swiss breed; group II – 60 cow-daughters of the Swiss breed. In a study of the polymorphism of the kappa-casein gene in cow-mothers and cow-daughters of the Swiss breed, the dominance of allele B (0.73 and 0.70) was found, which was registered more than two times more often than allele A. The incidence of genotypes AA – AB – BB in cow-mothers of the Swiss breed was as follows: 5.9% – 43.1% – 51.0% with indicators of observed heterozygosity 0.43 and expected heterozygosity 0.40. In cow-daughters of the Swiss breed the frequency of the BB genotype was the same, but, genotype AA was registered almost twice as often, with lower indicators of observed heterozygosity and smaller increases of indicators of expected heterozygosity than in cow-mothers. Cow-mothers of the Swiss breed with the AA genotype, in comparison with the AB genotypes, had higher milk yields during lactation (by 43%), fat production (by 86.9%), ratio of fat to protein (by 40.5%). Also note, the cow-mothers of the Swiss breed with the AA genotype, in comparison with the BB genotypes, had reliably high rates of fat to protein (by 35.8%) and only a trend to higher fat production; fat and protein. The production of fat in dairy cows-daughters with the BB genotype was higher than with the AA genotype, but only at the level of tendency. The correlation analysis showed that the AA genotype of the kappa-casein gene in cow-mothers of the Swiss breed was associated with the duration of lactation, indicators of milk yield during lactation, fat production, fat content and protein in milk with registration of reliable and positive coefficients of correlation. The genotypes in cow-daughters did not have a reliable correlation with the duration of lactation and fat or protein content in milk. The results of the kappa-casein gene polymorphism study indicated that the AA genotype of cow-mothers of the Swiss breed was associated with higher productive milk qualities which should be taken into account when forming a highly productive herd of cattle of the Swiss breed under intensiveoperative technology at a large-scale dairy unit.

Keywords: Brown Swiss cattle; alleles; genotypes AA, AB, BB of kappa-casein; milk yield; fat; protein.

Introduction

Today, Ukraine, like other countries, is demonstrating an increased concern about the scientific approach to increasing and improving the quality of agricultural products. This is especially true for the development of the dairy industry, because milk and dairy products are the most in-demand food products for both children and adults (Moshkovska, 2019; Shevchenko & Tabachuk, 2019). The State Statistics Service of Ukraine currently lists 1,667,000 head of cattle in the country and about 428,500 cows of various breeds are kept in the agricultural sector, but scientists and livestock experts are now striving to stabilize the number of cows and further increase it, especially at large-scale dairy units (Prokopenko, 2019). Therefore, contemporary studies by well-known researchers are now devoted to determining allelic variants of certain genes or genotypes of cows of highly productive breeds, which will allow selection of animals taking into account their genetic potential of high milk productivity, the implementation of which depends heavily on their yarding, feed quality and health conditions (Yoshida et al., 2009; Alim et al., 2014; Krupin et al., 2017). The studied kappa-casein gene (CSN3) is associated with milk protein and process milk properties (Sel'tsov et al., 2013; Zepeda-Batista et al., 2017). It is known that allele A of the kappa-casein gene is associated with increased milk yield in cows, and allele B is associated with a high fat and protein content in milk and better technological performance for the production of hard cheeses (Kopylov, 2010; Huiam et al., 2018). Therefore, the milk of cows with the genotype BB and AB capa-casein is characterized by a higher protein content and under the influence of enzyme rennet coagulates faster than the milk of cows with AA genotype (Pazzola et al., 2020; Doosti et al., 2011). Thus, to date, according to the literature, it is known that in Ukraine genetic study of cows was carried out by Suprovych & Mokhnachova (2017), who studied the polymorphism of kappa-casein (CSN3) genes in cows of the grey Ukrainian breed The researchers found that in cows of the grey Ukrainian breed the incidence of A allele of the kappa-casein CSN3 gene associated with increased milk yield was 60.7% and was significantly higher than the incidence of B allele associated with high protein content in milk and the best technological indicators for the production of hard cheeses were found in 39.3% of the population of this cow. But according to foreign literature data in the meta-analysis of the study of the influence of alleles A and B of the kappa-casein gene on milk yield and milk composition, it was found that selection based on allele B of kappa-casein can be used to improve the percentage of milk fat in dairy cows (Bangar et al., 2021). Thus, an increase in the population of the allelic variant B of capa casein makes it possible to obtain a higher yield of protein-dairy products, and the milk of such animals is desirable when used in the production of high-quality hard cheeses (Dolmatova & Ilyasov, 2011).

Kappa-casein of cattle is a phospho-protein with 169 amino acids encoded by a single polymorphic gene (CSN3) located on chromosome 6 of the genome of cows of different breeds (Samorè, 2012; Dolmatova & Va-

litov, 2015; Patel, 2018). Only two A and B allelic variants are used to analyze the kappa casein gene polymorphism because they occur in all breeds of cows. Variant B of the kappa-casein gene is the result of two point mutations – at positions 136 and 148, which lead to amino acid substitutions of Tyr-Iso and Ala-Asp (Suprovych & Mokhnachova, 2017). Nowadays, the study of milk productivity of cows associated with alleles or genotypes of specific genes responsible for the productive properties of cattle is topical and relevant. This will allow us to predict the lifetime milk productivity of cows, the quality of dairy products, to improve the selection work at large-scale dairy units (Volkandari et al., 2017; Barbosa et al., 2019; Ladyka et al., 2021). In addition, this work should confirm or refute the hypothesis that a certain genotype of the kappa-casein gene in the breed Swiss cows is associated with certain economically useful traits, such as high milk yields or protein and fat content. Therefore, the study of the regularity of distribution of kappa-casein gene genotype polymorphism in mothers and daughters of the Swiss breed cows, taking into account their milk productivity, is relevant.

Materials and Methods

The study is based of the principles the bioethics of according to the observance of the International Principles of the "European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes" (Strasbourg, 1985) accepted by the of Dnipro State Agrarian and Economic University's Bioethics Commission. The study of kappa-casein gene polymorphism (CSN3) was performed on 111 cows of the Swiss breed, which were kept under intensive operating conditions at a large-scale dairy unit "Ekaterinoslavsky" in Dnipropetrovsk region. The observation group I included 51 cow-mothers of the Swiss breed; group II – 60 cow-daughters of the Swiss breed.

Molecular-and-genetic studies on the genotyping of cattle were performed by the standard method of polymerase chain reaction using cows' venous blood, collected in vacuum tubes with EDTA. Genotyping was performed by the polymerase chain reaction method using the equipment 7500 Fast Real-Time System (Applied Biosystems, USA). The study used the total DNA samples isolated from whole venous blood using probes and primers TaqMan® Assay. Analysis of the study results was performed using the software 7500 Fast Real-time PCR Software (Applied Biosystems, USA). This research was carried out in the genetic laboratory "Angel milk" in the city of Kyiv in 2021.

In accordance with the results of molecular genetic studies, taking into account the Hardy-Weinberg law, to identify the genetic potential of the groups under study, the observed heterozygosity is this the number of heterozygotes for the studied allele divided by the sample size; the expected heterozygosity is defined if the sum of the squares of the allele frequencies is subtracted from one; Selender's coefficient for estimating the excess of heterozygotes in groups of cow-mothers and cow-daughters of the Swiss breed using the formula, where the mathematical difference between the observed heterozygosity and the expected heterozygosity is divided by expected heterozygosity (Suprovych & Suprovych, 2013).

Dairy productivity of cows was determined according to the indicators of control milkings in accordance with the rules for assessing the milk productivity of cows of dairy and meat breeds. At the same time, quantitative milk yield was studied for the entire lactation period and for 305 days of standardized lactation. The qualitative composition of milk with the determination of fat and protein and their mass fractions in milk was studied using analytical instruments Ekomilk 120 NPZ (Bulteh 2000 Ltd., Bulgaria, 2010) and Ekomilk Bond (Bulteh 2000 Ltd., Bulgaria, 2003). We also studied such economically useful features as: intensity of milk secretion, that is, the amount of milk per 1 day of lactation, 1 day of calving interval. Productive longevity was assessed by the number of lactations in the studied cows (Svezhentsov, 1998; Behma, 2018). The adaptation index was determined using the formula by Syratskiy et al. (1994), where the index of adaptation is mathematical difference between 365, is the number of days in the year, and the calving interval i.e., the interval between the last and previous calvings (days) divided by milk productivity of cows for the completed, shortened or for 305 days of lactation, expressed in kilograms of milk fat and multiplied by coefficient 27.4 (Pishchan, 2016). Statistical analysis of the study results was performed using the software Statistica 10, Version 10 (Data Analysis Software System, USA) with calculating the mean (x) and the standard error (SE) and correlation analysis with calculating Pearson's coefficient coefficient (r) and correlated error (S_r), if $P < 0.05$. The test for compliance of the control sample with the Hardy–Weinberg equilibrium was performed using the method of χ^2 with Yates adjustment ($P = 0.05$, $df = 1$). The probability of discrepancies between the mean values was determined using ANOVA with Bonferroni correction. The study results were statistically significant, if the indicators in the observation groups, when compared, had a difference of $P < 0.05$.

Results

This study investigated the distribution of allelic genes of the kappa-casein gene (CSN3) in cow-mothers and cow-daughters of the Swiss breed. It was proved that in both cow-mothers and cow-daughters of the Swiss breed, allele B was more often registered than allele A. So, in the cow-mothers, the frequency of allele B was recorded 2.6 times less than allele A. The cow-daughters of the Swiss breed had the allele B, which recorded 2.3 times less than allele A (Table 1). Accordingly, the milk of the Swiss breed cows with such genetic markers should be protein-containing, from which better quality hard cheeses can be made.

Table 1
Incidence of alleles of the kappa-casein gene
in mother-cows and daughter-cows of the Swiss breed

Groups of Swiss cows	Allele A incidence	Allele B incidence	Observed heterozygosity	Expected heterozygosity	χ^2	P
Cow-mothers (n = 51)	0.275	0.725	0.431	0.399	0.040	0.841
Cow- daughters (n = 60)	0.300	0.700	0.367	0.420	0.140	0.708

To assess genetic diversity, the observed heterozygosity and less sensitive to the sample size expected heterozygosity index were determined in the groups of cow-mothers and cow-daughters of the Swiss breed. According to Hardy-Weinberg's law, the absence of a significant difference between the observed and expected heterozygosity for the kappa-casein gene in both observation groups of cow-mothers and cow-daughters of the Swiss breed indicates the presence of an equilibrium between the incidences of homozygous and heterozygous which is passed on from generation to generation, and polymorphism of kappa casein is almost at the population level. At the same time, conditions of panmixia, absence of mutational pressure and selection pressure remain. That is, crossbreeding in the population or in the studied groups of the Swiss breed cows can be considered random or free, and selective pressure on alleles A or B can be considered absent. At the same time, the Selender's coefficient in the cow-mothers of the Swiss breed was 0.08, which indicated an excess of heterozygotes, and in the cow-daughters of the Swiss breed was –0.126 and the negative value of this coefficient still indicated a deficit of heterozygotes associated with selection measures in a group of the Swiss breed cow-daughters.

The study tested the distribution of genotypes and allelic genes of the kappa-casein gene (CSN3) in cow-mothers and cow-daughters of the Swiss breed. The homozygous genotype of BB in cow-mothers was recorded 8.6 times more often than the homozygous genotype of AA, but only in once more than the heterozygous genotype of AB. Also, the heterozygous genotype of AB in cow-mothers was found almost 7 times more often than the homozygous genotype of AA. In cow-daughters of the Swiss breed, the homozygous genotype of BB also prevailed. This is genotype of BB was recorded four times more often than the homozygous genotype of AA and almost once more than the heterozygous genotype of AB. Also, in the cow-daughters, the AB genotype was registered almost three times more often than the homozygous genotype of AA (Table 2).

Subsequently, the milk productivity of the Swiss breed cows was analyzed depending on the polymorphism of the kappa-casein gene. Among the studied groups of cows of the Swiss breed, regardless of genotypes, cow-mothers, of course, had a longer period of industrial use and productive longevity and at the time of the survey had 5.1 ± 0.2 lactation, and their cow-daughters of the Swiss breed had 1.8 ± 0.1 lactation.

Table 2
Incidence of genotypes of the kappa-casein gene in mother-cows and daughter-cows of the Swiss breed

Groups of Swiss cows	Genotype AA incidence	Genotype AB incidence	Genotype BB incidence
Cow-mothers (n = 51)	0.059	0.431	0.510
Cow-daughters (n = 60)	0.117	0.367	0.516
χ^2	0.530	0.250	0.010
P	0.467	0.617	0.906

The analysis of the data obtained indicated that there was a longer duration of lactation in cows of the Swiss breed with the AA genotype of the kappa-casein gene than those with AB and BB (244 and 240 milking days or 71.3% and 68.9%, Table 3). The results of this work proved that in cow-mothers of the Swiss breed, the AA genotype was associated with significantly higher milk yield per lactation, exceeding by 43.0% and 35.7% milk the yields of cows with AB and BB genotypes. The lowest milk yield was registered in cow-mothers of heterozygotes with AB genotype, but the milk yield per lactation was only 5.4% lower than in homozygotes with BB genotype.

Table 3
Dairy productivity of the cow-mothers of the Swiss breed, depending on the polymorphism genotypes of the kappa-casein gene (x ± SE)

Genotype (n)	Number of lactations (quantity)	Lactations duration (actual days nuber), days	Milk yield per lactation, kg	Milk yield for 305 days of the standard lactation, kg
AA (n = 3)	5.00 ± 1.00^a	587 ± 47^a	13613 ± 600^a	10040 ± 831^a
AB (n = 22)	5.36 ± 0.23^a	343 ± 21^b	9520 ± 609^b	8749 ± 373^a
BB (n = 26)	4.88 ± 0.22^a	347 ± 13^b	10030 ± 350^b	9215 ± 247^a

Note: different letters indicate values which reliably differed one from another within one table according to the Bonferroni correction.

A trend to longer duration of lactation is registered in cow-daughters with genotype AA compared to those of genotypes AB and BB (longer by 18.1% and 12.8%, respectively, Table 4). No such dependence was observed in cow-daughters of the Swiss breed, but higher milk yields per lactation were registered in cow-daughters with genotype AB: only 1.5% more than milk yields per lactation of cow-daughters with AA genotype and 2.3% more than those with BB genotype.

Table 4
Dairy productivity of the cow-daughters of the Swiss breed, depending on the polymorphism genotypes of the kappa-casein gene (x ± SE)

Genotype (n)	Number of lactations (quantity)	Lactations duration (days)	Milk yield per lactation, kg	Milk yield for 305 days of the standard lactation, kg
AA (n = 7)	1.71 ± 0.56^a	417 ± 63^a	9971 ± 523^a	9216 ± 412^a
AB (n = 22)	1.64 ± 0.16^a	353 ± 21^a	10125 ± 499^a	9320 ± 448^a
BB (n = 31)	1.90 ± 0.20^a	370 ± 15^a	9893 ± 279^a	9251 ± 211^a

Note: see Table 3.

However, the milk yield of cow-mothers of the Swiss breed with AA genotype exceeded the cow-daughters of the same breed with AA genotype by 36.5% ($P < 0.05$). At the same time, for 305 days of standardized lactation, only at the level of trends, was an excess of milk yield in cow-mothers of the Swiss breed with AA genotype noted (by 14.8%), which is more than in cow-mothers with AB genotype and only by 9,0% more than in cow-mothers of the Swiss breed with the BB genotype. Among heterozygous cow-daughters of the Swiss breed with AB genotype, for 305 days of standardized lactation, milk yields slightly exceeded milk yields of homozygous cow-daughters with AA genotype – by 1.13%, and with BB genotype – by 0.74%.

The quality of the Swiss breed cows' milk, taking into account the genotypes of the kappa-casein gene in cow-mothers and their daughters, was assessed, respectively, by relative and absolute indicators of fat, protein and their ratio in milk. Thus, it was found that in cow-mothers of the Swiss breed with homozygous AA genotype, the fat values significantly exceeded the same indicators of the cow-mothers with the AB genotype (by 327 kg or 86.9%) and only trend – with BB genotype (by 302 kg or 75.3%, Table 5).

Table 5
Productivity of fat and protein in cow-mothers of the Swiss breed, depending on the polymorphism genotypes of the kappa-casein gene (x ± SE)

Genotype (n)	Fat, %	Protein, %	Products, kg			Fat / protein, units
			fat, kg	protein, kg	fat + protein, kg	
AA (n=3)	5.22 ± 0.95^a	4.03 ± 0.52^a	703 ± 107^a	447 ± 98^a	1150 ± 206^a	1.63 ± 0.14^a
AB (n=22)	3.88 ± 0.12^a	3.36 ± 0.11^a	376 ± 30^b	328 ± 29^a	704 ± 57^a	1.16 ± 0.04^b
BB (n=26)	3.97 ± 0.12^a	3.31 ± 0.06^a	401 ± 21^a	332 ± 13^a	733 ± 33^a	1.20 ± 0.04^b

Note: see Table 3.

Also in the group of cow-mothers of the Swiss breed with the AA genotype, the production of fat and protein had a trend to exceeded by 446 kg (63.3%) and 417 kg (56.9%) the same indicators in cow-mothers with AB genotypes and BB genotypes. The ratio of fat to protein in cattle with AA genotype exceeded by 40.5% and 35.8% the same indicators in the groups of cow-mothers with AB and BB genotypes. At the level of the trend, the highest relative fat index was registered in cow-mothers of the Swiss breed with AA genotype, which was 1.3 times higher when compared with AB and BB genotypes. In contrast, the highest fat content in milk (by 6.2% – when compared with AA genotype and only by 1.8% – when compared with AB genotype) was registered in daughters of the Swiss breed with BB genotype (Table 6).

Table 6
Productivity of fat and protein in cow-daughters of the Swiss breed, depending on the polymorphism genotypes of the kappa-casein gene (x ± SE)

Genotype (n)	Fat, %	Protein, %	Products, kg			Fat / protein, units
			fat, kg	protein, kg	fat + protein, kg	
AA (n = 7)	3.73 ± 0.13^a	3.38 ± 0.06^a	371 ± 21^a	337 ± 18^a	708 ± 34^a	1.11 ± 0.06^a
AB (n = 22)	3.89 ± 0.16^a	3.34 ± 0.07^a	391 ± 25^a	337 ± 17^a	727 ± 40^a	1.16 ± 0.04^a
BB (n = 31)	3.96 ± 0.11^a	3.23 ± 0.06^a	392 ± 16^a	321 ± 11^a	713 ± 27^a	1.22 ± 0.02^a

Note: see Table 3.

Analysis of absolute data of the fat content in milk indicated that the production of fat in dairy cows with BB genotype only slightly exceeded these values in the groups with the AA genotype, by 21 kg. The ratio of fat to protein in cow-daughters with BB genotype exceeded the indicators registered in cow-daughters with AA and AB genotypes by 9.9% and 5.2% respectively. Accordingly, the indicators of fat production and the ratio of fat to protein in the milk of cow-mothers of the Swiss breed with AA genotype were by 89.4% ($P < 0.05$) and 46.9% ($P < 0.05$) higher than in cow-daughters that had genotype homozygous for allele A.

At the same time, the analysis of indicators characterizing the intensity of milk secretion indicated that both in cow-mothers and cow-daughters of the Swiss breed with AA gentype of kappa-casein gene polymorphism, the amount of milk per 1 day of lactation and per 1 day of calving interval was lower than in the respective groups of animals with AB and BB genotypes. That is, in the Swiss breed cow-mothers homozygous for allele A, the amount of milk per 1 day of lactation were lower by 8 kg or 50.3% ($P < 0.05$) and by 9 kg or 55.4% ($P < 0.05$) when compared with heterozygotes AB and homozygous genotype of BB. The milk yield per 1 day of calving interval was lower by 7 kg or 44.0% ($P < 0.05$) – when compared genotype of AA with genotype of BB (Tables 7).

Table 7
The intensity of milk secretion in the cow-mothers of the Swiss breed, depending on the polymorphism genotypes of the kappa-casein gene (x ± SE)

Genotype (n)	Milk quantity (kg) per:		Adaptation index, units
	1 lactation day, kg	1 day of calving interval, kg	
AA (n = 3)	18 ± 3^a	16 ± 2^a	-0.792 ± 0.185^a
AB (n = 22)	26 ± 1^b	22 ± 1^a	-0.080 ± 0.071^b
BB (n = 26)	27 ± 1^b	23 ± 1^b	-0.126 ± 0.040^b

Note: see Table 3.

However, in cow-daughters homozygous for A allele, only one trend was noted as to the amount of milk per one day of lactation and per one day of the calving interval, being lower by 15.2% and 13.9% when compared with AB heterozygotes and by 9.7% and by 8.9% when compared

with animals with BB genotype (Tables 8). The adaptability of Swiss cows was indicated by the adaptation index, and its value and negative sign indicated that the imbalance between the environment and the body of cattle was more pronounced in animals with homozygous AA genotype, especially in cow-mothers.

Table 8

The intensity of milk secretion in the cow-daughters of the Swiss breed, depending on the polymorphism genotypes of the kappa-casein gene (x ± SE)

Genotype (n)	Milk quantity per:		Adaptation index, units
	1 lactation day, kg	1 day of calving interval, kg	
AA (n = 7)	24 ± 2[a]	20 ± 1[a]	–0.318 ± 0.165[a]
AB (n = 22)	27 ± 1[a]	23 ± 1[a]	–0.105 ± 0.074[a]
BB (n = 31)	26 ± 1[a]	22 ± 1[a]	–0.194 ± 0.050[a]

Note: see Table 3.

The subsequent correlation analysis reflected the presence or absence of associations between genotypes of the kappa-casein gene and economic traits of cow-mothers and cow-daughters of the Swiss breed. According to our calculations, the values of the correlation coefficients (r) fluctuated within moderate and weak correlation.

The system of relationships between genotypes and indicators of milk productivity and reproductive capacity in the Swiss breed cows was characterized by the following associative connections. Thus, the AA genotype of the kappa-casein gene in cow-mothers of the Swiss breed had positive relationships with the duration of lactation or the number of active days ($r = 0.58 \pm 0.12$, $P < 0.05$); and indicators of milk yield per lactation ($r = 0.37 \pm 0.13$, $P < 0.05$); milk fat production ($r = 0.32 \pm 0.14$, $P < 0.05$) and fat content ($r = 0.41 \pm 0.13$, $P < 0.05$) and protein ($r = 0.36 \pm 0.13$, $P < 0.05$) in milk. At the same time, in cow-daughters of the Swiss breed, the AA genotype was only not a reliable and weak trend with the duration of lactation ($r = 0.20 \pm 0.13$). The BB genotype in the Swiss breed cow-daughters had only not a reliable and a weak negative tendency with the relative protein content in milk ($r = –0.20 \pm 0.13$).

Discussion

Further, we compared the obtained data on the distribution of genotypes of the studied kappa-casein gene in cows of the Swiss breed with the known results of studies by contemporary researches, which have great variability. Thus, according to foreign research from Turkey, which studied the polymorphism of the kappa-casein gene in cows of the Swiss breed kept in Ankara, Kayseri, Nevşehir, Yozgat, it was only in Ankara, that the incidence of alleles A and B was detected as 0.444 and 0.556, respectively. In cows of the Swiss breed from Ankara, the incidence distribution of alleles A and B was also 0.443 and 0.557. In this case, the distribution of genotypes of the polymorphism of the kappa-casein gene had the following pattern: AA = 0.140, BB = 0.252, AB = 0.608 (in the Swiss breed from Ankara only AA = 0.182, BB = 0.295, AB = 0.523). The observed heterozygosity was 0.607, and the expected heterozygosity was 0.496, in the Swiss breed cows kept in Ankara only observed heterozygosity was 0.523, while the expected heterozygosity was 0.499 (Bilal et al., 2012, 2014). However, in our study, the incidence of allele A was recorded almost 1.6 times less than in cow-mothers and 1.5 times less than in cow-daughters of the Swiss breed. Accordingly, the incidence of allele B in our study, on the contrary, was registered almost 1.3 times more often in both cow-mothers and cow-daughters. However, according to our results, both in cow-mothers and in cow-daughters of the Swiss breed, BB genotype was registered two times more often, and the incidence of AA genotype was close to the above literature data. And only AB genotype registered in cow-mothers was met 1.4 times less frequently, and in cow-daughters – almost 1.7 times less frequently than in cows of the Swiss breed kept in Turkey. According to our data, the observed heterozygosity indicator was also lower (1.4 times in cow-mothers and almost 1.8 times in cow-daughters) and only the expected heterozygosity in cow-daughters of the Swiss breed was close to the values provided in literature data. However, in their recent studies, Murad Gurses et al, who also studied the kappa-casein gene polymorphism in the Swiss breed cows kept in Ceylanpinar, Karakoy and Sultansuyu state farms of Turkey, reported the following: A and B alleles incidences were equal to 0.357 and 0.643; the incidence of AA – AB – BB genotypes was 0.152 – 0.410 – 0.438, and the observed heterozygosity index was 0.410, the expected heterozygosity index was 0.459 (Gurses et al., 2018).

When estimating the genetic polymorphism of the kappa-casein gene in the Romanian brown breed cows, it was found that the most common allele in the CSN3 locus was B allele (0.694) and A allele (0.30600 was rarer). The distribution of AA – AB – BB genotypes corresponded to 0.0746 – 0.4627 – 0.4627 (Ilie et al., 2017). This data was partially close to our results. Thus, in our study, the incidence of alleles A and B in mother-cows was as follows: 0.275 and 0,725 and in daughter-cows: 0.300 and 0.700; incidence of genotypes AA – AB – BB in cow-mothers of the Swiss breed was equal to: 0.059 – 0.431 – 0.510 with indicators of observed heterozygosity 0.431 and expected heterozygosity 0.399 in cow-daughters of the Swiss breed: 0.117 – 0.367 – 0.516, with indicators of observed heterozygosity 0.367 and expected heterozygosity 0.420. Suprovych & Mokhnachova (2017) studied the polymorphism of kappa-casein (CSN3) genes in grey cows and showed that the incidence of homozygous cows AA was 36.9%, BB – 15.5%, and heterozygous AB – 47.6% (almost half of the animals), but no significant differences between these indicators were registered. Indicators of the observed heterozygosity and expected heterozygosity were 0.476 and 0.477, respectively (Suprovych & Mokhnachova, 2017). In our study, on the contrary, the incidence of allele A significantly exceeded (more than two times) the incidence of allele B in both cow-mothers and cow-daughters of the Swiss breed, but the incidence of heterozygous genotype AB in cow-mothers was recorded with incidence of 43.1% with actual or observed heterozygosity 0.431, which was close to the results of the above study. In grey cows of the Ukrainian breed from the farm of State Enterprise Research Center "Polyvanivka", Dnipropetrovsk region, for the CSN3 kappa-casein gene, on the contrary, allele A was registered in 35% and allele B in 65% and this data approached the incidence of allele A distribution (27.5% in cow-mothers and 30.0% in cow-daughters) and allele B (72.5% in cow-mothers and 70.0% in cow-daughters) of the Swiss breed, which were kept at a large-scale dairy unit "Ekaterinoslavsky", which is also located in the Dnepropetrovsk region. In this case, homozygous type AA was only in 2.5% of animals, homozygous type BB – in 32.5%, heterozygous genotype AB was in 65% of animals, with a statistically significant difference, while the observed heterozygosity and expected heterozygosity was 0.650 and 0.455 (Kostyunina et al., 2011; Suprovych & Mokhnachova, 2017). Comparing this data with the results of our study, it can be stated that the incidence of AA genotypes was registered two times more often in cow-mothers of the Swiss breed and almost five times more often in cow-daughters of the Swiss breed. Also, the homozygous BB genotype of the kappa-casein gene was registered in cattle of the Swiss breed almost 1.5 times more often, both in cow-mothers and cow-daughters, and the heterozygous AB genotype, on the contrary, was registered 1.5 times less often in cow-mothers and 1.8 times less often than cow-daughters of the Swiss breed. Also, the indicators of actual heterozygosity were 1.5 and 1.8 times lower in cow-mothers and cow-daughters of the Swiss breed, but with almost the same indicator of the expected heterozygosity in cow-daughters.

Kopylov (2010), Ukraine, found that for the kappa-casein gene in the black-spotted dairy breed the incidence of the AA genotype was 0.664 (66.4%), that is, much more often than in cow-mothers and cow-daughters of the Swiss breed (AB – 0.312 (31.2%), BB – 0.024 (2.4%)). Cows of Ukrainian red-spotted dairy breed had the following distribution of genotypes by the gene of kappa-casein (AA – 0.778 (77.8%), AB – 0.222 (22.2%)), and animals with BB genotype were not detected. In Simmentals, the AA genotype was in 0.467 (46.7%) of cases, AB – 0.425 (42.5%), BB – 0.108 (10.8%). In Holstein cows, homozygous AA variant was registered in 0.793 (79.3%) of animals, heterozygous AB – 0.207 (20.7%), homozygous BB – was not detected (Kopylov, 2010). The genotypic characteristics of Holstein cows from Ukraine were close to the results of a study by foreign researchers that evaluated the effects of genetic polymorphism of the Kappa-casein gene on milk productivity of Holstein cattle in Slovakia and established their genotypic population structure with determining allele and genotype incidences. Thus, it was found that in the Holstein cattle from Slovakia all three genotypes were identified – AA

(69.5%), AB (27.6%) and BB (2.9%), and the incidence of allele A was 83.3%, and allele B – 16.7% (Miluchová et al., 2018). It should be noted that when studying the polymorphism of the kappa-casein gene in Holstein cows from Turkey and Macedonia, the researchers also registered the results that were close to the above values of the genotypes incidence, namely: AA (72.7% and 54.7%), AB (22.7% and 36%) and BB (4.5% and 9.3%), and the incidence of A allele was 84.1% and 72.7%, and B allele – 15.9% and 27.3% (Bilal et al., 2012; Adamov et al., 2020).

In Indian cows, the calculated allele incidences for A and B were also 0.79 and 0.21, respectively (Deb et al., 2014). Analysis of literature data indicated that in Ukraine genetically similar breeds based on allele A were: Ukrainian black-spotted dairy breed (incidence of A allele was 82%, Ukrainian red-spotted dairy breed (incidence of A allele – 88.8%, Holstein breed (incidence of A allele – 89.6%) (Kopylov, 2010). This data coincided with the results of Bangar et al. (2021), who conducted a meta-analysis of the incidence of alleles of the kappa-casein gene in 5,715 genotyped cows in a random effects model and proved that allele A predominated with an incidence of 0.71 (95% DI: 0.65, 0.76). At the same time, according to the results of our research, the Swiss breed cows, on the contrary, genetically differed from them in the incidence of distribution of allelic genes A and B of the kappa-casein gene both in cow-mothers (27.5% and 72.5%) and in cow-daughters (30.0% and 70.0%). Kopylova et al. (2010) with colleagues, as well as in our study, did not find a significant difference between the observed actual and expected heterozygosity in cows of red dairy breed, which were kept on two different breeding farms: observed heterozygosity – 0.444–0.611, expected heterozygosity – 0.384–0.424.

In the study of cattle productive properties, depending on the polymorphism of the kappa-casein gene, in the studies of scientists, it was proved that cows of the black-spotted breed with homozygous AA genotype of the kappa-casein gene had a higher milk yield, as well as fat content, and these data coincide with the results of our study, which are reliably confirmed in cows of the Swiss breed (Kostyunina et al., 2011; Plivachuk & Dyman', 2015). When studying the relationship between the milk yield of Holstein cows in Slovakia and their genetic characteristics of the kappa-casein gene polymorphism (CSN3), it was established that the AA genotype of the kappa-casein gene was associated with higher milk yield (850,165 kg) and fat production, while the protein production in milk, in contrast, was higher in Holstein cows with the BB genotype, which significantly reduced their breeding value (Miluchová et al., 2018). But in our study, there was a correlation between AA genotype and higher values of not only milk yield and fat but also protein production in cow-mothers of the Swiss breed, while higher milk yield and fat production were registered in the group of animals with AB genotype, fat in milk – in cow-daughters of Swiss breed with BB genotype, and vice versa, higher protein production was registered in animals with AA genotype. In the study of Swiss cows from Turkey, a trend to form a relationship between the AA genotype and higher milk yields (4491 ± 185 kg) was also noted, while the BB genotype was associated with significantly higher protein content (3.478 ± 0.044%) and the trend to higher fat content (4.417 ± 0.290%) in milk (Gurses et al., 2018). But in cows of Indian origin, the studied association of genotypes of the kappa-casein gene with certain traits of milk productivity proved that, conversely, only heterozygous AB genotype has a significant ($P < 0.05$) effect on milk yield, compared with AA genotype (Deb et al., 2014). Also, the polymorphism of the kappa-casein gene (CSN3) with the assessment of milk productivity by milk yield, milk fat and milk protein, was studied in black-and-white breed cows and Bestuzhev and Simmental breeds. At the same time, the highest rates of milk yield and milk protein belonged to animals with B allele of kappa-casein (Dolmatova & Valitov, 2015).

At the same time, such a pattern was not recorded in our study in mothers and daughters of the Swiss breed. The cow-daughters of the Swiss breed tested in the study had the highest milk yield in heterozygotes AB genotype of kappa-casein gene. The higher content of fat and protein in milk was registered in cows-mothers of the Swiss breed (5.22 ± 0.95% and 4.03 ± 0.53%) with a homozygous AA genotype of the kappa-casein gene. The cow-daughters of the Swiss breed did not demonstrate such a pattern. Dairy cows of the Holmogorsk breed of Tatarstan type with the AA genotype of the kappa-casein gene (CSN3) had the largest increase in milk productivity, fat content (3.73 ± 0.09%), as in our study in cow-mothers of the Swiss breed, and with genotypes AB and BB – protein in milk up to 3.30 ± 0.02% and 3.31 ± 0.04%, respectively. Energy content of 670 kcal was characteristic of animals with AA and BB genotypes (Gribanova & Kurak, 2012). It was also found that cows of Ukrainian dairy breed with homozygous BB genotype for the kappa-casein gene had higher milk yields at I, II and III lactations than with AB and AA genotypes, which contradicted the data obtained in both cow-mothers and cow-daughters of the Swiss breed in accordance with the results of our study. The milk fat content in Ukrainian dairy cows, as well as in cows of the Swiss breed according to our data, was also the highest in the group of animals with the AA genotype, but in the cows of the Swiss breed in our study, the highest fat content in milk (3.96 ± 0.112%) was registered in a group of animals with BB genotype (Dolmatova & Ilyasov, 2011). In general, at the present stage, some scientists propose to improve the technological properties of milk by selecting cows with B alleles of milk proteins by the kappa-casein gene (Dolmatova & Valitov, 2015; Suprovych & Mokhnachova, 2017).

However, this data does not coincide with the results of our study and with some of the above literature data. Thus, cow-mothers of the Swiss breed had more positive correlations, and the positive dependencies can be considered more stable than the only trends registered in cow-daughters. Comparison of our study results with data from the literature testified to different asociative relationships between certain genotypes of cows of both the Swiss and other breeds with indicators of their productive qualities, which in the future, substantiates the need for further research in this area.

Conclusion

Molecular-genetic study of the distribution patterns of allelic genes and genotypes of the polymorphism of the kappa-casein (CSN3) gene in the cow-mothers and cow-daughters of the Swiss breed showed that the frequency of occurrence of the B allele was significantly higher than the A allele (72.5% and 70.0% vs. 27.5% and 30.0%, respectively). In this case, the homozygous BB genotype was registered most often (51.0% and 51.6%); heterozygous genotype AB (43.1% and 36.7%) – rarely registered and homozygous AA (5.9% and 11.7%) – very rarely registered.

The homozygous AA genotype of the kappa-casein gene in the cow-mothers is associated with the higher milk yields during lactation (13613 ± 600 kg), fat (703 ± 107 kg) and the ratio of fat to protein (1.63 ± 0.14 units). Among homozygous cow-daughters of the Swiss breed with BB genotype the production of fat in milk slightly exceeded fat of homozygous cow-daughters with AA genotype of the kappa-casein gene (by 5.7%). The correlation analysis test of the genotypes of the kappa-casein (CSN3) gene polymorphism can be used for prognosis of lactation duration, milk yield, fat and protein in milk for improvement of breeding and productive qualities of cows of Swiss breed. It is recommended to continue the study tests to increase the productive longevity of cows of the Swiss breed and improve their economic and useful traits, which are controlled by the gene described.

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