Association of complex genotypes of kappa-casein and diacylglycerol O-acyltransferase from milk production in different lines cows

I O Efimova¹*, L R Zagidullin², R R Shaidullin³, T M Akhmetov², S V Tyulkin³ and A B Moskvicheva³

¹Department of Morphology, Obstetrics and Therapy, Chuvash State Agricultural Academy, 29, Karl Marx Str., Cheboksary, 428003, Russian Federation
²Department of mechanization named after N.A. Safiullina and Department of Biological Chemistry, Physics and Mathematics, Kazan State Academy of Veterinary Medicine named after N.E. Bauman, 35, Siberian tract, Kazan, 420029, Russian Federation
³Department of Biotechnology, Livestock and Chemistry, Kazan State Agrarian University, 65, Karl Marx Str., Kazan, 420015, Russian Federation

E-mail: vet2@edu.academy21.ru

Abstract. The aim of the investigation was to observe the frequency of complex genotypes CSN3/DGAT1 occurrence and their effect on the milk production of different lines cows. It was found that in the herd of cows 4 genotypes CSN3 AA / DGAT1 A K and CSN3 AB / DGAT1 AA, CSN3 AA / DGAT1 AA, CSN3 AB / DGAT1 AK predominate with a frequency of occurrence of more than 7.3%, notably that the greatest number of combinations are found in the lines of M. Chiftein and R. Sowering. The best indices of milk yield (5736 and 5401 kg), milk fat (208 and 201 kg), milk protein (179 and 170 kg) in the lines of V.B. Aydial and R. Sowering were noted in first-calf heifers with the AB/AK genotype. A significant difference (P<0.05-0.01) in milk yield, fat and protein in the Sowering line was found between the combinations AB/AK and AA/AA, and AB/AK and AB/KK. In M. Chiftein's line, the highest milk yield (5045 kg), milk fat (182 kg) and protein (163 kg) were detected in the CSN3 BB / DGAT1 AA genotype, when exceeding the combination of AA/AA and AA/AK (P<0.05-0.01). In high-producing cows V.B. Aydial’s line has the highest milk productivity in cows with the genotype CSN3 AA / DGAT1 AA, when animals with the genotypes AB/AK and AB/KK are exceeded (P<0.05-0.01).

1. Introduction

Nowadays, thanks to the rapid introduction of DNA technologies, the total number of genetic markers detected in farm animals has already reached several dozens, which allows having tight control over considerable part of its genome [1].

Kappa-casein and diacylglycerol O-acyltransferase genes are among the most common potential DNA markers of milk productivity character in cattle. Milk genes are highly polymorphic and there are several allelic variants. Many investigations have been devoted to the study of genetic markers’ polymorphism of cow milk production [2-5].
The kappa-casein protein gene (CSN3) is associated with character of milk protein and the technological properties of milk. The structure of kappa-casein is controlled by one polymorphic gene located in the 6th chromosome of the cattle genome [6-8].

The diacylglycerol O-acyltransferase (DGAT1) gene is located in the 14th chromosome of the cattle genome and it is defined as a genetic marker which affects milk quality. This DGAT1 gene is used in lipid biosynthesis and it is associated with butter-fat yielding capacity of cow [9-10].

Nowadays, market demands are increasing in regards to the quality of milk and dairy products, particularly to fat content, the quantity and composition of milk protein, as well as the using of fat and milk protein in the production of dairy products, there is a need of identifying and using genetic markers which are associated with selection of milk production qualitative character. As a result, the genes markers of milk productivity, such as the kappa-casein gene and O-acyltransferase diacylglycerol gene, are of greatest interest in regards to selection [11-14].

Genetic diversity and polymorphism must be considered in studying characteristic features of lines to accelerate the selection progress. It will give the opportunity to establish the prospects of utilized selection methods and it will be able to use them in breeding preferable type of animals [15, 16].

In this regard, cattle genotyping by genetic marker should be used not only on the scale of the herd as a whole, but also on individual genealogical lines. At the same time, it is possible to select animals with the consideration of the genotype by DNA markers with the consideration of a given linear herd structure [17, 18].

The aim of this investigation was to study the incidence of complex genotypes for two genes simultaneously - kappa-casein and diacylglycerol O-acyltransferase and their effect on the milk production of different lines cows.

2. Materials and methods
First-calf heifers and high-producing Black-and-White cows were selected at LLC “Dusym” in the Atnya district of Tatarstan Republic to determine the polymorphism of the kappa-casein (CSN3) and diacylglycerol O-acyltransferases (DGAT1) genes.

The livestock of dairy cattle belonged to the lines of the Holstein breed: Vis Back Aydial 101341, Montvik Chiftein 95679, Reflection Sowering 198998, S.T. Rokit 252803 were under the investigation.

The material for DNA testing was venous blood of experimental animals. DNA was isolated from each blood sample using the kit “Magnosorb” (Interlabservis, Moscow, Russia) according to the manufacturer's instructions. The CSN3 gene was studied by polymerase chain reaction method followed by analysis of restriction fragment length on polymorphism (PCR-RFLP) using the forward primer 5'-TAGCCAAATATATCCCAATTCGTT-3' and reverse primer 5'-TTATATTAAGTCCATGAATCTTG-3' [19]; the DGAT1 gene was studied by using the forward primer 5'-GCTGCTCTGAGGGCCCTTCG-3' and reverse primer 5'-GCCGGCGCCTTCATGCCCT-3' [20]. Amplification with primers was performed by amplifier “Tertsik” (“DNA technology”, Moscow, Russia) according to standard practice. It was used PCR mixture of the following composition: a pair of primers for amplification of the studied gene, a mixture of nucleoside triphosphates (2.5 mM), magnesium chloride (25mM), ten-fold PCR buffer, Taq polymerase.

The derived amplicons were exposed to restriction using restriction enzymes Hinf I (CSN3 gene) and Eae I (DGAT1 gene) (SibEnzyme, Russia) according to the manufacturer's recommendations. After hydrolysis, the amplicon fragments were exposed to horizontal electrophoresis in a 2.5% agarose gel.

After restriction, the amplicon fragments were exposed to horizontal electrophoresis in a 2.5% agarose gel. For staining and visualization of fragments, agarose gels after electrophoresis were kept in a 0.005% solution of ethidium bromide for 15 minutes and they were fixed using the GelDoc system (Bio-Rad, USA). The molecular weights of the fragments were determined according to the “ladder” of molecular weight standards, which were accelerated in parallel with the amplicon fragments.
All results were statistically processed using the Microsoft Excel software application from the Microsoft Office 2007 software package.

3. Results and discussion
It was found that only 8 complex genotypes were identified in the studied group of first-calf cows.

The most common genotypes in animals of all lines are CSN3 AA / DGAT1 AK and CSN3 AB / DGAT1 AA, so in cows of the line V.B. Aydial 58.6% and 19.5%, M. Chiftein - 38.8% and 12.2%, R. Sowering - 33.3% and 16.7%, S.T. Rokit - 46.1% and 30.8% (table 1).

Table 1. The degree of incidence of kappa-casein and diacylglycerol O-acyltransferase genotypes combinations in first-calf heifers and high-producing cows of different lines.

| Genotype by genes | The frequency of the genotypes combinations |  |
|-------------------|--------------------------------------------|--|
|                   | first-calf heifers | high-producing cows |  |
|                   | n | % | n | % |  |
| V.B. Aydial       |  |  |  |  |  |
| AA/AA             | 5 | 12.2 | 18 | 29.5 |  |
| AA/AK             | 24 | 58.6 | 16 | 26.2 |  |
| AA/KK             | 1 | 2.4 | 2 | 3.3 |  |
| AB/AA             | 8 | 19.5 | - | - |  |
| AB/AK             | 3 | 7.3 | 20 | 32.8 |  |
| AB/KK             | - | - | 4 | 6.6 |  |
| BB/AK             | - | - | 1 | 1.6 |  |
| M. Chiftein       |  |  |  |  |  |
| AA/AA             | 6 | 12.2 | 23 | 41.8 |  |
| AA/AK             | 19 | 38.8 | - | - |  |
| AA/KK             | 2 | 4.1 | 3 | 5.5 |  |
| AB/AA             | 6 | 12.2 | 3 | 5.5 |  |
| AB/AK             | 10 | 20.4 | 22 | 40.0 |  |
| AB/KK             | 1 | 2.0 | 1 | 1.8 |  |
| BB/AA             | 2 | 4.1 | - | - |  |
| BB/AK             | 3 | 6.2 | 2 | 3.6 |  |
| BB/KK             | - | - | 1 | 1.8 |  |
| R. Sowering       |  |  |  |  |  |
| AA/AA             | 7 | 19.4 | 33 | 47.9 |  |
| AA/AK             | 12 | 33.3 | 6 | 8.7 |  |
| AA/KK             | 1 | 2.8 | - | - |  |
| AB/AA             | 6 | 16.7 | 3 | 4.3 |  |
| AB/AK             | 6 | 16.7 | 19 | 27.5 |  |
| AB/KK             | 2 | 5.5 | 3 | 4.3 |  |
| BB/AA             | 1 | 2.8 | 1 | 1.5 |  |
| BB/AK             | 1 | 2.8 | 4 | 5.8 |  |
| S.T. Rokit        |  |  |  |  |  |
| AA/AA             | 3 | 23.1 | 3 | 16.7 |  |
| AA/AK             | 6 | 46.1 | 9 | 50.0 |  |
| AB/AA             | 4 | 30.8 | 4 | 22.2 |  |
| AB/AK             | - | - | 2 | 11.1 |  |

The heterozygous genotype CSN3 AB / DGAT1 AK is well represented in cows of M. Chiftein (20.4%) and R. Sowering (16.7%), and it is absent in the line of S.T. Rokit. Also, in these lines, a combination of the homozygous genotype CSN3 AA / DGAT1 AA is observed with a frequency from
12.2% to 23.1%. The share of each remaining genotypes did not exceed 7.3% and their total percentage in the line of V. B. Aidial was no more than 9.7%, in M. Chiftein line it was 16.4%, in R. Sowning line it was 13.9%. The combination of CSN3 BB / DGAT1 KK was not identified in the herd of first-calf heifers.

Only 9 complex genotypes were found in the highly productive part of the herd. Therewith combinations of the genotypes CSN3 AA / DGAT1 AA (29.5-47.9%), CSN3 AB / DGAT1 AK (27.5-40.0%) are often found, the genotypes CSN3 AA / DGAT1 AA (50.0%) and CSN3 AB / DGAT1 AA (22.2%) are often found in cows of the C.T. Rokit line.

The genotypes CSN3 AA / DGAT1 KK, CSN3 AB / DGAT1 KK, CSN3 BB / DGAT1 AK, CSN3 BB / DGAT1 AA have the lowest degree of incidence, and the combination CSN3 BB / DGAT1 KK is available only in M. Chiftein cows.

In the structure of the dairy herd, first-calf heifers and high-producing cows of LLC “Dusym” have a smaller part of the combinations CSN3 BB / DGAT1 AA (2.8-4.1%), CSN3 BB / DGAT1 AK (1.6-5.8%) and CSN3 BB / DGAT1 KK (1.8%), all of them are found in animals of the M. Chiftein line.

Milk production indices were determined in cows with complex CSN3/DGAT1 genotypes (table 2).

| Genotype CSN3 / DGAT1 | Milk production, kg | Fat, % | Milk fat, kg | Protein, % | Milk protein, kg |
|-----------------------|---------------------|--------|--------------|------------|-----------------|
| **V.B. Aidial**       |                     |        |              |            |                 |
| AA/AA                 | 4331±113            | 3.60±0.02 | 156±3.5   | 3.08±0.01 | 133±3.6         |
| AA/KA                 | 4647±82             | 3.62±0.02 | 168±2.9   | 3.12±0.01 | 145±2.4         |
| AA/KK                 | 4268                | 3.68   | 157        | 3.15      | 134             |
| AB/AA                 | 4432±349            | 3.64±0.02 | 161±12.4  | 3.15±0.02 | 140±11.4        |
| AB/AK                 | 5736±736            | 3.63±0.06 | 208±27.1  | 3.12±0.05 | 179±24.2        |
| **M. Chiftein**       |                     |        |              |            |                 |
| AA/AA                 | 4054±104            | 3.62±0.04 | 147±2.5   | 3.12±0.02 | 126±2.7         |
| AA/KA                 | 4276±75             | 3.66±0.02 | 156±2.5   | 3.14±0.01 | 134±2.2         |
| AA/KK                 | 4133±51             | 3.84±0.10 | 159±3.9   | 3.20±0.02 | 132±0.5         |
| AB/AA                 | 4375±203            | 3.63±0.05 | 159±6.5   | 3.11±0.03 | 136±5.4         |
| AB/AK                 | 4562±139            | 3.69±0.03 | 168±5.6   | 3.17±0.01 | 145±5.0         |
| AB/KK                 | 4245                | 3.71   | 157        | 3.17      | 135             |
| BB/AA                 | 5045±283            | 3.60±0.05 | 182±10.2  | 3.24±0.04 | 163±11.2        |
| BB/AK                 | 4566±430            | 3.71±0.05 | 169±13.9  | 3.28±0.03 | 150±12.9        |
| **R. Sowering**       |                     |        |              |            |                 |
| AA/AA                 | 4426±145            | 3.60±0.03 | 159±5.7   | 3.10±0.01 | 137±4.4         |
| AA/KA                 | 4866±134            | 3.59±0.01 | 175±23.7  | 3.10±0.01 | 151±20.3        |
| AA/KK                 | 4528                | 3.90   | 177        | 3.24      | 147             |
| AB/AA                 | 4865±244            | 3.63±0.02 | 176±9.4   | 3.13±0.03 | 152±7.5         |
| AB/AK                 | 5401±317            | 3.73±0.05 | 201±10.1  | 3.14±0.02 | 170±9.4         |
| AB/KK                 | 4070±50             | 3.80±0.04 | 155±3.3   | 3.19±0.01 | 130±1.8         |
| BB/AA                 | 4540                | 3.54   | 161        | 3.20      | 145             |
| BB/AK                 | 4807                | 3.74   | 180        | 3.29      | 158             |
| **S.T. Rokit**        |                     |        |              |            |                 |
| AA/AA                 | 4158±206            | 3.68±0.04 | 153±6.3   | 3.11±0.04 | 129±5.0         |
| AA/KA                 | 4186±121            | 3.67±0.01 | 154±4.6   | 3.14±0.02 | 131±3.8         |
| AB/AA                 | 3992±253            | 3.68±0.03 | 147±9.1   | 3.17±0.02 | 126±8.0         |
The best indicators in the lines of V.B. Aydial and R. Sowering were found in the genotype CSN3 AB / DGAT1 AK for milk yield (5736 and 5401 kg), mass fraction of fat (208 and 201 kg), mass fraction of protein (179 and 170 kg) (table 2). A significant difference in the Sowering line was found between combinations of the AB/AK and AA/AA, and AB/ AK and AB/KK genotypes for milk yield 975 kg (P<0.05) and 1331 kg milk (P<0.01), in yield milk fat 42 kg and 46 kg (P<0.01), the yield of milk protein 33 kg and 40 kg (P<0.01), and the mass fraction of fat only between the genotypes AB/ AK and AA/AA – 0.13% (P<0.05).

In M. Chiftein's line, the highest milk productivity was detected in the genotype CSN3 BB / DGAT1 AA for milk yield (5045 kg), mass fraction of fat (182 kg), mass fraction of protein (163 kg), and the difference was statistically significant compared with the combination of AA/AA and AA/AK for the yield of 991 kg and 769 kg of milk (P<0.05), the yield of milk fat 35 kg and 26 kg (P<0.05), the mass fraction of protein in milk 0.12% and 0.10% (P<0.05), the yield of milk protein is 37 kg and 29 kg (P<0.05), as well as the milk yield compared to the AB/ AK genotype - 0.13% (P<0.05).

In line S.T. Rokit, the difference between the groups was not appreciable and proved.

When comparing the CSN3 AB / DGAT1 AK group between the cows of the Sowering and Chiftein line, a significant advantage was noted in the former line in milk per 839 kg of milk (P<0.05), in the amount of milk fat by 33 kg (P<0.05) and the amount of milk protein per 25 kg (P<0.05). In the Sowering line, high milk yield is observed in animals with a combination of CSN3 AA / DGAT1 AK and significantly predominate the similar genotype in the Chiftein line by 610 kg (P<0.001), in the Rokit line by 700 kg (P<0.01). The difference is also significant for the CSN3 AB / DGAT1 AA genotype as compared to the Rokit line - 873 kg of milk (P<0.05).

Table 3 shows the milk production of high-producing cows with combinations of the kappa-casein and diacylglycerol O-acyltransferase genotypes of different lines. In the line of V.B. Aydial the highest milk productivity was observed in cows with the genotype CSN3 AA / DGAT1 AA, however they significantly dominate over the genotype AB/ AK and AB/KK in milk yield by 464 kg (P<0.01) and 691 kg of milk (P<0.001), in milk fat by 13 kg (P<0.05) and 14 kg (P<0.05), in milk protein by 13 kg (P<0.05) and 14 kg (P<0.05). In terms of the mass fraction of fat in milk, the difference is significant between AB/KK and AA/AA - 0.19% (P<0.05) and AB/KK and AA/AK - 0.26% (P<0.01) in favor first.

In M. Chiftein's line, high milk productivity (6038 kg), the yield of milk fat (222 kg) and protein (189 kg) was detected in the CSN3 AB / DGAT1 AA group and they subsequently have a significant domination over the AA/KK genotype by 515 kg of milk (P<0.01), 11 kg (P<0.05) and 13 kg (P<0.01). Maximum milk protein is observed in cows with the genotype CSN3 BB / DGAT1 AK (3.28%) with a highly significant (P<0.001) domination over the AA/AA groups by 0.15%, AA/KK by 0.24%, AB/ AK by 0.16%.

High milk productivity in the R. Sowering line was observed in cows with a combination of the CSN3 AB / DGAT1 AK genotypes, while significantly higher than the AB/AA group in milk yield per 729 kg of milk (P<0.01), in the mass fraction of fat in milk per 0.12% (P<0.05), in the yield of milk fat per 33 kg (P<0.001), in the mass fraction of protein in milk by 0.14% (P<0.001), in the yield of milk protein by 31 kg (P<0.001). Animals with the CSN3 AB / DGAT1 KK genotype dominate over all other groups in terms of fat content by 0.22-0.34% (P<0.05-0.001). And cows with a combination of CSN3 BB / DGAT1 AK in the mass fraction of protein in milk significantly dominate over the genotype AA/AK and AB/AA by 0.17% (P<0.05), and in the amount of milk protein they dominate only over AB/AA - by 32 kg (P<0.05).

Line S.T. Rokit showed a good level of milk productivity in animals with a combination of AA/AA and AA/AK, and the genotypes AB/AA and AB/AK have a good level about all other indicators of milk productivity.
Table 3. Milk productivity of high-producing cows with combinations of kappa-casein and diacylglycerol O-acyltransferase genotypes of different lines.

| Genotype | Milk production, kg | Fat, % | Milk fat, kg | Protein, % | Milk protein, kg |
|----------|---------------------|--------|--------------|------------|-----------------|
|          | V.B. Aydial         |        |              |            |                 |
| AA/AA    | 6463±140            | 3.59±0.02 | 232±5.0       | 3.08±0.02  | 199±4.3        |
| AA/AK    | 6163±100            | 3.52±0.02 | 217±3.7       | 3.09±0.02  | 190±3.0        |
| AA/KK    | 5919±286            | 3.63±0.03 | 215±8.9       | 3.14±0.01  | 186±9.3        |
| AB/AA    | 5999±94             | 3.65±0.03 | 219±3.5       | 3.11±0.02  | 186±2.8        |
| AB/KK    | 5772±36             | 3.78±0.09 | 218±3.9       | 3.21±0.07  | 185±4.2        |
| BB/AK    | 6347                | 3.42    | 217           | 3.15       | 200            |
|          | M. Chiftein         |        |              |            |                 |
| AA/AA    | 6038±114            | 3.67±0.02 | 222±4.0       | 3.13±0.02  | 189±3.7        |
| AA/KK    | 5700±225            | 3.77±0.10 | 215±4.2       | 3.04±0.01  | 173±6.6        |
| AB/AA    | 5523±98             | 3.83±0.13 | 211±3.4       | 3.19±0.03  | 176±1.7        |
| AB/AK    | 6001±100            | 3.69±0.03 | 221±3.8       | 3.12±0.02  | 187±3.0        |
| AB/KK    | 5344                | 4.07    | 218           | 3.08       | 165            |
| BB/AK    | 5971±249            | 3.57±0.01 | 213±8.6       | 3.28±0.01  | 196±8.5        |
| BB/KK    | 6122                | 3.66    | 224           | 3.13       | 192            |
|          | R. Sowingering       |        |              |            |                 |
| AA/AA    | 6182±142            | 3.61±0.02 | 223±5.2       | 3.11±0.02  | 192±4.7        |
| AA/AK    | 6086±272            | 3.58±0.04 | 218±8.0       | 3.05±0.02  | 186±7.3        |
| AB/AA    | 5564±192            | 3.57±0.03 | 199±5.5       | 3.05±0.01  | 170±6.0        |
| AB/AK    | 6293±120            | 3.69±0.03 | 232±4.5       | 3.19±0.03  | 201±4.5        |
| AB/KK    | 6118±350            | 3.91±0.08 | 239±14.7      | 3.19±0.06  | 195±14.9       |
| BB/AA    | 6610                | 3.65    | 241           | 3.20       | 212            |
| BB/AK    | 6286±361            | 3.65±0.05 | 229±16.2      | 3.22±0.06  | 202±13.8       |
|          | S.T. Rokit           |        |              |            |                 |
| AA/AA    | 5891±312            | 3.62±0.02 | 213±12.1      | 3.18±0.03  | 187±8.3        |
| AA/AK    | 5804±299            | 3.63±0.05 | 211±12.3      | 3.09±0.03  | 179±10.2       |
| AB/AA    | 5783±260            | 3.76±0.11 | 217±6.7       | 3.18±0.04  | 184±7.8        |
| AB/AK    | 5760±460            | 3.79±0.11 | 218±11.4      | 3.17±0.04  | 182±12.5       |

When comparing different lines with each other within the same combination of genotypes, it was found that in the group with the genotype CSN3 AA / DGAT1 AA, CSN3 AA / DGAT1 AK and CSN3 AA / DGAT1 KK, an advantage in the level of milk productivity was noted in cows of V.B. Aydial line.

The combination of the AB/AK, AB/KK and BB/AK genotypes showed the best milk productivity in animals of the R. Sowering line, but the difference was statistically significant for the AB/AK group in terms of milk protein yield comparing to the V.B. Aydial line - 15 kg (P<0.01) and M. Chiftein - 14 kg (P<0.05).

In the group CSN3 AB / DGAT1 AA, the highest milk production was observed in cows of the M. Chiftein line (3.83%), in the AB/KK group it was in R. Sowering line (3.91%), in the AB/AK group it was in S.T. Rokit line (3.79%). In terms of the mass fraction of protein in milk, the difference is significant for the CSN3 AA / DGAT1 KK combination between the Aydial and Chiftein lines in favor of the first by 0.10% (P<0.01), for the CSN3 AB / DGAT1 AA group it is significant between the Chiftein and Sowering lines in favor of the first by 0.14% (P<0.05).

4. Conclusion

In the dairy herd of LLC “Dusym”, 4 complex genotypes CSN3 AA / DGAT1 AK and CSN3 AB /
DGAT1 AA, CSN3 AA / DGAT1 AA, CSN3 AB / DGAT1 AK prevail, notably that the largest number of combinations are found in the lines of M. Chiftein and R. Sowering. The genotypes CSN3 BB / DGAT1 AA, CSN3 BB / DGAT1 AK and CSN3 BB / DGAT1 KK were the rarest with a frequency of less than 5.8%.

The cows with a combination of CSN3 AA / DGAT1 AK and CSN3 AB / DGAT1 AK genotypes had high milk productivity.

When selecting bulls in linear breeding, one should take into account their allelic polymorphism according to the CSN3 and DGAT1 genes and it is necessary to use more extensively P. Sowering lineage producers to obtain highly productive offspring, which have the kappa-casein allele B and K diacylglycerol O-acyltransferase allele in the genotype.

References

[1] Zinoviev N A, Gladir E A and Kostyunina O W 2004 DNA diagnostics of gene polymorphism - cattle milk proteins. Research methods in biotechnology of farm animals (Moscow) p 7-22 [In Russian]

[2] Avilés C, Polvillo O, Pena F, Juarez M, Martinez A and Molina A 2015 Associations between DGAT1, FABP4, LEP, RO RC, and SCD1 gene polymorphisms and fat deposition in Spanish commercial beef. J Anim Sci. 91 (10) 4571–4577 doi.org/10.2527/jas.2013-6402

[3] Ganiev A S, Shaibullin R R, Sibagatullin F S, Sharafutdinov G S, Moskvicheva A B, Tyulkin S V and Faizov T H 2018 Reproductive quality of cows of different genotypes on CSN3 and DGAT1 genes depending on milk level. Research Journal of Pharmaceutical, Biological and Chemical Sciences 9 (6) 1504-1509

[4] Dolmatova I Yu and Valitov F R 2015 Assessment of the genetic potential of cattle by marker genes. Bulletin of Bashkir University 20 (3) 850 [In Russian]

[5] Epishko O A, Tanana L A, Peshko V V and Trahimchik R V 2014 Polymorphism of milk productivity genes in the cattle population of the Republic of Belarus. Collection of scientific papers of the North Caucasus Research Institute of Animal Husbandry 3 (1) 41 [In Russian]

[6] Zinoviev N A and Gladir E A 2001 The use of DNA diagnostics for the analysis of candidate genes for loci of quantitative traits of farm animals. Scientific works of the All-Russian Institute of Livestock 61 218 [In Russian]

[7] Soloshenko V A, Popovski Z T, Goncharenko G M, Petukhov V L, Grishina N B, Shishin N I and Kamaldinov E V 2016 Association of polymorphism of κ-casein gene and its relationship with productivity and qualities of a cheese production. Research Journal of Pharmaceutical, Biological and Chemical Sciences 7 (4) 3214-3221

[8] Tyulkin S V, Vafin R R, Zagidullin L R, Akhmetov T M, Petrov A N and Diel F 2018 Technological properties of milk of cows with different genotypes of kappa-casein and betalactoglobulin. Foods and Raw Materials 6 (1) 154-162 doi: 10.21603/2308-4057-2018-1-154-162

[9] Bennewitz J, Reinsch N, Paul S, Loof C, Kaupe B, Weimann C, Erhardt G, Thaller G, Kuhn Ch, Schwerin M, Thomsen H, Reinhardt F, Reents R and Kalm E 2004 The DGAT1 K232A Mutation is not solely responsible for the milk production quantitative trait locus on the bovine chromosome 14. J. Dairy Sci. 87 (2) 431-442 doi: 10.3168/jds.S0022-0302(04)73182-3

[10] Lacorte G A, Machado M A, Martinez M L, Campos A L, Maciel R P, Verneque R S, Teodoro R L, Peixoto M G, Carvalho M R and Fonseca C G 2006 DGAT1 K 232A polymorphism in Brazilian cattle breeds. Genet Mol Res. 5 (3) 475-482

[11] Goncharenko G M, Goryacheva T S, Medvedev N S, Grishina N B, Akulich E G and Kononenko E V 2013 K-casein gene polymorphism and cheese-making traits of milk from Simmental cows. Achievements of science and technology of the agro-industrial complex 10 45 [In Russian]

[12] Grashin V A and Grashin A A 2011 DNA technology - the direction of increasing milk protein.
Dairy and beef cattle breeding 3 18 [In Russian]

[13] Ozdemir M, Kopuzlu S, Topal M and Bilgin O C 2018 Relationships between milk protein polymorphisms and production traits in cattle: a systematic review and meta-analysis. Arch. Anim. Breed 61 197-206 doi: 10.5194/aab-61-197-2018

[14] Molee A, Duanghaklang N and Na-Lampang P 2012 Effects of acyl-CoA:diacylglycerol acyl transferase 1 (DGAT1) gene on milk production traits in crossbred Holstein dairy cattle. Trop. Anim. Health Prod. 44 (4) 751-755 doi: 10.1007/s11250-011-9959-1

[15] Klenovitsky P M, Marzanov N S, Bagirov V A and Nasibov M G 2004 Genetics and biotechnology in animal breeding (Moscow: Explorer) p 285 [In Russian]

[16] Fedoseeva N A, Sanova Z S, Mazurov V N and Myshkina M S 2018 Milk productivity of cows, depending on their origin. Bulletin of the Michurinsk State Agrarian University 2 136 [In Russian]

[17] Zinnatova F F, Yulmetieva Yu R, Zinnatov F F and Shakirov Sh K 2015 Interlinear polymorphism of the kappa-casein gene in the cattle heifers population. Issues of legal regulation in veterinary medicine 4 180 [In Russian]

[18] Shaydullin R R, Sharafutdinov G S, Moskvichyova A B, Ziganshin B G and Tyulkin S V 2019 Interlinear polymorphism of the kappa-casein gene and its effect on the milk production of cows. Achievements of the science of technology of the agro-industrial complex 33(5) 51-54 doi: 10.24411/0235-2451-2019-10512 [In Russian]

[19] Kalashnikova L A, Dunin I M, Glazko V I, Ryzhova N V and Golubina E P 1999 DNA technology for assessing farm animals (Lesnye Polyany: VNIIplem) p 148 [In Russian]

[20] Spelman R J, Ford C A, McElhinney P, Gregory G C and Shell R G 2002 Characterization of the DGAT1 gene in the New Zealand dairy population. J. Dairy Sci. 85(12) 3514-3517 doi: 10.3168/jds.S0022-0302(02)74440-8