Fatty acid composition of blood lipids of young beef cattle of different genotypes of CAPN1, GH, TG5, LEP genes

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Abstract. The results of genotyping of beef cattle (bull-calves of white-faced and Kazakh white-headed cattle) made it possible to establish the features of gene polymorphism ensuring meat efficiency (CAPN1, GH, TG5, LEP). Genotype carriers of selection significant alleles marking high efficiency and quality of beef are revealed. Superiority by body weight, daily average gains of homozygous (CAPN1CC GHLL TG5TT LEPTT) genotypes in comparison with alternative (CAPN1GG GHVV TG5CC LEPCC) genotypes was established in the selection of white-faced bull-calves by 13.2 and 14.9%, Kazakh white-headed – by 11.8 and 13.3%. The fatty acid composition of blood lipids of young white-faced, Kazakh white-headed cattle of different genotypes is defined. The features of fatty acid composition of blood lipids depending on pedigree and genotype of animals expressed by integrated indicators characterizing the intensity of biosynthesis of fatty acids are established: index of lipid saturation (ILS), index of lipid exchange intensity (ILEI), metabolism efficiency ratio of essential fatty acids (MER). The determined stable correlation of integrated indicators of lipid exchange intensity with body weight and daily average gains gives grounds for their use as biochemical test systems during lifetime assessment of young cattle breeding potential.

1. Introduction
At present, the creation of beef cattle breeding as a supplier of high-quality beef is an essential problem. This problem may be partially solved through scientific support of livestock industry with the methods of objective assessment of animals at early age thus combining information on QTL genetic markers on the one hand, and biological opportunities of an animal organism on the other [1, 2]. Currently, due to the progress in molecular genetics technologies, the range of markers of cattle productivity is quite wide: calpain (CAPN1) controlling the quality of meat, its tenderness, marbling [3], somatotropin (GH) – key regulator of somatic growth of animals [4, 5], thyroglobulin (TG5) playing a key role in exchange processes [6], leptin (LEP) regulating energy metabolism thus ensuring the balance of fat accretion in tissues [7, 8]. Information on biological status revealing the metabolism mechanism, which covers unique biochemical features that serve as biomarkers [9, 10], is particularly important to understand the potential of breeding animals. Along with their caloric value, the fatty acids of blood lipids are characterized by a special biological role: they form part of many active agents, control and normalize exchange processes and have different biological activity: arachidonic acid is twice more active than...
linoleic and linolenic acids, and the level of palmitic acid indicates the level of biosynthesis of fatty acids while the level of oleic acid – their catabolism [11, 12].

Such constants as the index of lipid saturation (ILS), index of lipid exchange intensity (ILEI) and conversion efficiency ratio of essential fatty acids (MER) serve the estimated criteria of fatty acids metabolism efficiency, their biosynthesis and their efficiency in metabolic processes [13]. It is proved that the level of biosynthesis of fatty acids in the organism of more highly productive animals is higher than that of less productive [14, 15].

The above confirms and since to blood lipids, their fatty acid composition play a key role in various systems and organs, and their level is genetically determined [16, 17], then they can serve as objective biochemical tests to assess the physiological state and intensity of metabolism. Live-animal estimate on the basis of genotyping and biochemical testing will allow maintaining the uniqueness of allelofund of valuable beef cattle species well adapted to a specific zone of breeding.

The purpose of the study is to analyze the fatty acid composition of blood lipids of young beef cattle of different genotypes of CAPN1, GH, TG5, LEP genes and to prove its use as a biomarker during live-animal estimate of meat efficiency.

2. Materials and methods
The experiment was performed on young bull-calves of white-faced and Kazakh white-headed cattle. DNA from blood of experimental animals with a set of reagents DIAtom®DNAprep (IsoGeneLab, Moscow) was used for genotyping. The polymorphism of GH, TG5, LEP genes was studied on the basis of PCR-RFLP with subsequent restriction analysis (Table 1).

| Gene | Nucleotide sequence | Amplification size, n/n | T, °C, primer annealing | Endonuclease | Genotypes |
|------|---------------------|-------------------------|-------------------------|--------------|-----------|
| GH   | F:5'-gtgctctgacctg -3' | 223                     | 65                      | AluI         | LL/LV/VV |
|      | R:5'-gcggcgccttgactcct-3' |                   |                         |              |           |
| TG 5 | F:5'-ggtggtagctgcttgactc-3' | 548                    | 62                      | BsTx21       | TT/TC/CC |
|      | R:5'-gtctttgacgctgttaata-3' |                   |                         |              |           |
| LEP  | F:5'-tggagtgtgctttctct-3' | 442                    | 62                      | BstMBI       | TT/TC/CC |
|      | R:5'-gtcctttcttcgctacaat-3' |                   |                         |              |           |

Polymorphism of calpain gene (CAPN1) was studied by RT-PCR with application an allele specific probes to define one binary SNP mutation of C316G using CAPN1-detekt set (Sintol, Russia) and the analyzer of nucleotide acids ANC-32 (Russia).

Methylation of fatty acids of blood plasma was carried out by Morrison and Smith’s technique. The analysis of methyl ethers of fatty acids was carried out via gas-liquid chromatography on gas chromatograph Crystal-200 with capillary column HP-FFAP 50 m 0.32 mm 0.5 pm (USA). The Chromatec Analytic software was used to process the chromatographic information. The following indicators were used as estimated (integrated) criteria characterizing intensity and orientation of lipid exchange: index of lipid saturation (ILS) – relation of the sum (Σ) of saturated to the sum (Σ) of unsaturated [18], index of lipid exchange intensity (ILEI) – relation of the quantity of palmitic (C16:0) acid to the quantity of oleic acid (C18:1) [19], metabolism efficiency ratio of essential fatty acids (MER) – relation of the quantity of arachidonic acid (C20:4) to the sum of all other polyunsaturated fatty acids with carbon chain ranging from 20 to 22 carbon atoms [20].
3. Results and discussion
The analysis of genotyping of young white-faced and Kazakh white-headed cattle species revealed that the polymorphism of genes controlling meat efficiency is presented by two alleles and three genotypes: CAPN1 gene – alleles C and G, genotypes CC, CG, GG; GH gene – alleles L and V, genotypes LL, LV, VV; TG5 gene – alleles T and C, genotypes TT, TC, CC; LEP gene – alleles T and C, genotypes TT, TC, CC with a different frequency of occurrence. Relatively similar, but low frequency of occurrence of allele C of CAPN1 gene was identified among bull-calves of white-faced species (0.19), Kazakh white-headed species (0.13), but high (0.81 and 0.87) allele G that created a situation rather low (5.0%) frequencies of occurrence of a homozygous CC genotype and high allele GG (67.0 and 80.0%).

The polymorphism of GH gene is characterized by relatively identical distribution of alleles L and V in the studied selections of young cattle, which made respectively 0.35 and 0.39; 0.65 and 0.61, thus ensuring the presence of homozygous (LL; VV) and heterozygous (LV) option of genotypes: 18.0; 49.0 and 33.0% – white-faced species, 32.0; 54.0 and 14.0% – Kazakh white-headed species. Quite often (0.31) allele T of TG5 gene was typical for bull-calves of white-faced species, rarer (0.21) – Kazakh white-headed species. The revealed situation was reflected by the frequency of occurrence of homozygous (a TT, CC) and heterozygous (CU) genotypes, respectively: 16.0; 55.0 and 29.0% – Herefords, 5.0; 64.0 and 31.0% – Kazakh white-headed species (Table 2).

Table 2. CAPN1, GH, TG5, LEP genes polymorphism of beef cattle (bull-calves)

| Index | CAPN1 genotype | GH genotype | TG5 genotype | LEP genotype |
|-------|----------------|--------------|--------------|--------------|
|       | CC (C) | CG (G) | GG (L) | LL (L) | LV (V) | VV (V) | TT (T) | TC (C) | CC (C) | TT (T) | TC (C) | CC (C) |
| allele frequency | 0.19 | 0.81 | 0.35 | 0.65 | 0.31 | 0.69 | 0.20 | 0.80 |
| Genotype frequency | 0.05 | 0.28 | 0.67 | 0.18 | 0.33 | 0.49 | 0.16 | 0.29 | 0.55 | 0.06 | 0.29 | 0.65 |
| Genotype frequency, % | 5.0 | 28.0 | 67.0 | 18.0 | 33.0 | 49.0 | 16.0 | 29.0 | 55.0 | 6.0 | 29.0 | 65.0 |

Kazakh white-headed cattle (n=93)

| Allele frequency | 0.13 | 0.87 | 0.39 | 0.61 | 0.21 | 0.79 | 0.25 | 0.75 |
| Genotype frequency | 0.05 | 0.15 | 0.80 | 0.32 | 0.14 | 0.54 | 0.05 | 0.31 | 0.64 | 0.10 | 0.31 | 0.59 |
| Genotype frequency, % | 5.0 | 15.0 | 80.0 | 32.0 | 14.0 | 54.0 | 5.0 | 31.0 | 64.0 | 10.0 | 31.0 | 59.0 |

The typical feature of both inter- and mixed bred differentiation of LEP gene polymorphism was relatively equally low (0.20; 0.25) frequency of occurrence of allele T, but high (0.80; 0.75) – allele C, which was reflected by the presence of homozygous (TT, CC) and heterozygous (CU) genotypes: 6.0; 65.0 and 29.0%; 10.0; 59.0 and 31.0%, respectively.

The genetic and statistical analysis revealed that the share of animals with desirable complex genotype including combinations of 8 marker alleles of four genes (CAPN1(CC GH(L(T.5 TT LEP(T.5)) made 5.6%, combinations of 6 marker alleles of three genes (GH(L(T.5 TT LEP(T.5)) 18.3%, combinations of 4 marker alleles of two genes (GH(L(T.5 TT) – 29.7%, combinations of two marker alleles of one gene (GH(L(T.5) – 42.4% – in the selection of young white-faced cattle, 3.4; 15.8; 33.6; 48.8% – Kazakh white-
headed cattle. The analysis of genotyping demonstrates that the specific weight of selection significant genotypes in the studied selections of young meat breeds was quite similar (Table 3).

| Breed                        | Selection significant genotypes |
|------------------------------|---------------------------------|
|                              | CAPN1<sup>CC</sup> | GH<sup>LL</sup>TG5<sup>TT</sup> | LEP<sup>TT</sup> | GH<sup>HL</sup>TG5<sup>TT</sup> | GH<sup>HL</sup> |
| white-faced cattle           | 5.6                 | 18.9                         | 29.7             | 42.4                     |
| Kazakh white-headed cattle   | 3.4                 | 15.3                         | 32.2             | 45.2                     |

The comparative analysis of fatty acid composition of blood lipids of young white-faced and Kazakh white-headed cattle demonstrates similarity of its qualitative composition, which was expressed by high level of such acids as palmitic (C<sub>16:0</sub>), stearin (C<sub>18:0</sub>), oleic (C<sub>18:1</sub>), linoleic (C<sub>18:2</sub>) at relatively low level of myristic (C<sub>14:0</sub>), pentadecanoic (C<sub>15:0</sub>), heptadecane (C<sub>17:0</sub>), heptadecenoic (C<sub>17:1</sub>), and arachidonic (C<sub>20:4</sub>) – polyunsaturated or perchloric fatty acids. The comparison and analysis of fatty-acid profile of blood lipids of the studied young cattle revealed that the fatty acid composition of blood lipids of young white-faced cattle is characterized by bigger aggregate number of both saturated and unsaturated fatty acids, namely: ∑ saturated – 46.07, ∑ monounsaturated – 31.56, ∑ polyunsaturated – 25.44% against 41.58; 28.21; 22.72% – Kazakh white-headed cattle. At the same time the level of palmitic (C<sub>16:0</sub>), stearin (C<sub>18:0</sub>), oleic (C<sub>18:1</sub>) acids was 10.5 higher than the
fatty acids playing a key role in lipid exchange by 10.5; 8.5; 10.8% (P<0.05) respectively in blood lipids of young white-faced cattle.

Table 5. Total amount of fatty acids of blood lipids of beef cattle of different genotypes (bull-calves aged 8 months)

| Genotype | white-faced cattle | Kazakh white-headed cattle |
|----------|--------------------|---------------------------|
|          | Σ saturated | Σ monounsaturated | Σ polyunsaturated | Σ saturated | Σ monounsaturated | Σ polyunsaturated |
| CAPN1    |            |                    |                  |            |                    |                  |
| CC       | 47.12±0.06  | 30.85±0.06         | 25.16±0.05       | 46.43±0.06 | 29.46±0.03         | 25.81±0.05       |
| GG       | 44.35±0.03  | 28.18±0.05         | 24.84±0.04       | 44.03±0.05 | 27.81±0.04         | 24.98±0.03       |
| LH       | 45.33±0.04  | 31.93±0.04         | 26.73±0.01       | 44.91±0.06 | 30.37±0.04         | 25.71±0.01       |
| VV       | 42.18±0.01  | 28.56±0.06         | 25.15±0.03       | 42.29±0.04 | 30.33±0.03         | 23.99±0.02       |
| TT       | 46.33±0.06  | 28.93±0.04         | 25.91±0.05       | 45.77±0.06 | 31.85±0.05         | 26.30±0.04       |
| TG5      |            |                    |                  |            |                    |                  |
| CC       | 43.67±0.05  | 26.49±0.03         | 24.73±0.03       | 43.66±0.04 | 30.85±0.03         | 24.60±0.05       |
| TT       | 41.63±0.05  | 29.14±0.04         | 24.85±0.04       | 42.03±0.02 | 30.84±0.02         | 24.75±0.02       |
| LEP      |            |                    |                  |            |                    |                  |
| CC       | 39.05±0.03  | 27.85±0.05         | 22.46±0.02       | 39.75±0.01 | 29.85±0.01         | 22.66±0.01       |

The comparative analysis of fatty acid composition of blood lipids of the studied young cattle of different genotypes revealed that the total amount of saturated and unsaturated fatty acids was higher in blood lipids of homozygous CAPN1CC GHLL TG5TT LEPtt genotypes in comparison with alternative CAPN1GG GHVV TG5CC LEPcc genotypes: by 5.8 and 5.4; 6.9 and 8.4; 5.7 and 6.6; 6.2 and 6.8% – Herefords, by 5.1 and 4.5; 5.8 and 6.7; 4.6 and 4.6; 5.4 and 5.5% – bull-calves of Kazakh white-headed cattle (Table 5).

The comparison and analysis of obtained data showed that irrespective of the breed the maximum digital values of studied integrated indicators were typical for homozygous CAPN1CC GHLL TG5TT LEPtt genotypes in comparison with alternative CAPN1GG GHVV TG5CC LEPcc genotypes with superiority in ILS on average by 10.5-11.5%, in ILEI on average by 8.5-10.0%, in MER on average by 9.6-13.0% (Table 6).

Considering high biochemical activity of fatty acids, it is possible to assume that the revealed regularity is a consequence of active biosynthesis of fatty acids caused by their intensive use from blood pool for growth and development of an organism in general, formation of muscular tissue, in particular. The revealed assumption was confirmed though comparative assessment of body weight and daily average gain of young beef cattle of different genotypes (Table 7).
Table 6. Integrated indicators of lipid exchange intensity of bull-calves of different genotypes

| Genotype | $\sum_{n} \sum_{n_{op}} = \text{ILS}$ | $C_{16:0}C_{18:1} = \text{ILEI}$ | $C_{20:4}C_{18:2} = \text{MER}$ |
|----------|--------------------------------------|-----------------|-----------------|
| CAPN1    | white-faced cattle (n=98)            |                 |                 |
| CC       | 0.87                                 | 0.78            | 0.23            |
| GG       | 0.79                                 | 0.72            | 0.20            |
| GH       | 0.84                                 | 0.69            | 0.18            |
| VV       | 0.73                                 | 0.63            | 0.16            |
| TG5      | 0.86                                 | 0.77            | 0.21            |
| TT       | 0.75                                 | 0.68            | 0.18            |
| LEP      | 0.77                                 | 0.67            | 0.22            |
| CC       | 0.69                                 | 0.59            | 0.10            |
| Kazakh white-headed cattle (n=93) |                 |                 |                 |
| CAPN1    | 0.88                                 | 0.75            | 0.22            |
| GG       | 0.80                                 | 0.70            | 0.20            |
| GH       | 0.82                                 | 0.74            | 0.20            |
| VV       | 0.72                                 | 0.68            | 0.18            |
| TG5      | 0.83                                 | 0.79            | 0.20            |
| TT       | 0.74                                 | 0.71            | 0.18            |
| LEP      | 0.78                                 | 0.74            | 0.21            |
| CC       | 0.70                                 | 0.67            | 0.19            |

Table 7. Body weight, daily average gain of beef cattle of different genotypes (bull-calves)

| Genotype | white-faced cattle (n=98) | Kazakh white-headed cattle (n=93) |
|----------|---------------------------|----------------------------------|
|          | body weight, kg           | daily average gain, g            | body weight, kg         | daily average gain, g    |
|          | born                      | 8 months                        | born                    | 8 months                |
| CAPN1    | 28.1±0.22                 | 224.4±7.75                     | 26.8±0.47               | 214.2±7.65             |
| CC       | 27.6±0.18                 | 192.3±7.10                     | 25.4±0.41               | 185.4±6.96             | 666.6±39.72 |
|GG        | 28.3±0.19                 | 226.8±8.02                     | 26.5±0.35               | 219.6±7.19             | 804.5±39.27 |
|GH        | 28.0±0.15                 | 196.4±7.86                     | 25.9±0.27               | 194.5±6.85             | 702.5±40.12 |
|VV        | 28.1±0.26                 | 224.9±8.68                     | 25.4±0.29               | 212.6±7.62             | 780.0±38.82 |
|TT        | 27.9±0.14                 | 197.3±8.92                     | 24.9±0.31               | 188.9±6.89             | 683.3±39.75 |
|LEP       | 27.9±0.24                 | 222.1±8.12                     | 25.2±0.29               | 214.6±7.74             | 789.1±40.36 |
|CC        | 28.2±0.29                 | 193.8±7.98                     | 26.3±0.21               | 189.9±6.97             | 681.6±39.69 |

This regularity was mostly typical for homozygous CAPN1<sup>CC</sup> GH<sup>LL</sup> TG5<sup>TT</sup> LEP<sup>TT</sup> genotypes and made 0.38 and 0.31; 0.39 and 0.38; 0.39 and 0.33; 0.37 and 0.32 – white-faced cattle, 0.32 and 0.28; 0.36 and 0.34; 0.36 and 0.30; 0.34 and 0.32 – Kazakh white-headed cattle.

The analysis of obtained data allows concluding that the integrated indicators reflecting the intensity of lipid exchange depend on gene genotype controlling meat efficiency and can be used as a biomarker for live-animal estimate of animal productivity at early age.
The analysis of body weight and daily average gain revealed that irrespective of the breed, homozygous genotypes, carriers of selection significant alleles CAPN1\textsuperscript{CC} GH\textsuperscript{LL} TG5\textsuperscript{TT} LEP\textsuperscript{TT} of 8 month old cattle were higher their herdmates with alternative CAPN1\textsuperscript{GG} GH\textsuperscript{VV} TG5\textsuperscript{CC} LEP\textsuperscript{CC} genotypes by 14.3 and 16.1; 13.4 and 15.1; 12.3 and 13.9; 12.7 and 14.7% – young white-faced cattle, by 13.4 and 14.6; 11.4 and 12.7; 11.1 and 12.3; 11.5 and 13.6% – Kazakh white-headed cattle.

The results of correlative analysis indicate positive and reliable relation between integrated indicators of lipid exchange and size body weight, as well as daily average gains of all considered genotypes of the studied breeds of beef cattle. Besides, it was much higher for MER of blood lipids and body weight, daily average gains (Table 8).

### 4. Conclusion

The study and the analysis of obtained results allows concluding that the integrated approach that identifies resistant associations of gene complexes (genetic markers) controlling economic qualities and unique biochemical parameters (test system) on the one hand ensures objectivity of live-animal estimate of genetic potential of breeding animals at early age, and on the other hand – acceleration and increase of selection efficiency.

### 5. Acknowledgments

The studies were carried out in accordance with the research plan for 2019-2020 of the Federal Research Center for Biological Systems and Agrotechnology of the Russian Academy of Sciences (No. 0761-2019-0009).

### References

[1] Soloshenko V A, Goncharenko G M, Dvoryatkin A A and Pleshakov V A 2013 On the possibility of using genetic markers in selection of meat cattle to improve meat quality \textit{Bull. of meat cattle breeding} \textbf{1(79)} 37–40

[2] Bakhtushkina I A, Khramtsova A and Podkorytov A T 2016 Meat qualities of beef cattle raised in Altai Republic \textit{Bull. of Altai State Agricultural University} \textbf{4(140)} 163–7

| Genotype | Body weight white-faced cattle (n=98) | Daily average gain Kazakh white-headed cattle (n=93) |
|----------|------------------------------------|-----------------------------------------------|
|          | ILS | ILEI | MER | ILS | ILEI | MER |
| CAPN1    |     |      |      |      |      |      |
| CC       | 0.20 | 0.26 | 0.38 | 0.23 | 0.28 | 0.31 |
| GG       | 0.15 | 0.19 | 0.22 | 0.17 | 0.21 | 0.22 |
| GH       |     |      |      |      |      |      |
| LL       | 0.28 | 0.26 | 0.39 | 0.26 | 0.42 | 0.38 |
| VV       | 0.13 | 0.18 | 0.17 | 0.19 | 0.24 | 0.21 |
| TG5      |     |      |      |      |      |      |
| TT       | 0.24 | 0.21 | 0.39 | 0.22 | 0.13 | 0.33 |
| LEP      |     |      |      |      |      |      |
| TT       | 0.18 | 0.22 | 0.37 | 0.21 | 0.26 | 0.32 |
| CC       | 0.11 | 0.17 | 0.19 | 0.17 | 0.19 | 0.21 |
| CAPN1    |     |      |      |      |      |      |
| CC       | 0.19 | 0.23 | 0.32 | 0.22 | 0.26 | 0.28 |
| GG       | 0.17 | 0.19 | 0.21 | 0.17 | 0.17 | 0.22 |
| GH       |     |      |      |      |      |      |
| LL       | 0.21 | 0.33 | 0.36 | 0.19 | 0.27 | 0.34 |
| VV       | 0.15 | 0.14 | 0.21 | 0.14 | 0.18 | 0.22 |
| TG5      |     |      |      |      |      |      |
| TT       | 0.23 | 0.20 | 0.36 | 0.14 | 0.26 | 0.30 |
| CC       | 0.17 | 0.19 | 0.16 | 0.21 | 0.28 | 0.11 |
| LEP      |     |      |      |      |      |      |
| TT       | 0.21 | 0.26 | 0.34 | 0.25 | 0.26 | 0.32 |
| CC       | 0.17 | 0.19 | 0.24 | 0.19 | 0.21 | 0.18 |
[3] Shakirov Sh K, Yulmetyeva Yu R and Gafurova L I 2014 Molecular and genetic aspects of meat cattle selection by marbling Bull. of meat cattle breeding 2(85) 59–64
[4] Surundaeva L G, Maevskaya L A and Kosyan D B 2012 Use of DNA markers to define CAPNI gene polymorphism of beef cattle Bull. of meat cattle breeding 4(78) 41–5
[5] Selionova M I, Chizhova L N, Dubovskova M P, Surzhikova E S, Kononova L V and Sharko G N 2017 Features of gene polymorphism of growth hormone (GH), calpain (CAPN1) of beef herd sire Bull. of meat cattle breeding 2(98) 65–70
[6] Sedykh T A, Kalashnikova L A, Gusev I V, Pavlova I Yu, Gizatullin R S and Dolmatova I Yu 2016 Influence of TG5 and LEP gene polymorphism on quantitative and qualitative meat composition in beef calves Iraqi J. of Veterinary Sci. 30 2 41–8
[7] Komisarek J 2010 Impact of LEP and LEPR gene polymorphisms on functional traits in Polish Holstein-Friesian cattle Animal Sci. Papers and Reports 10 133–41
[8] Sasazaki S, Akiyama K, Narukami T, Matsumoto H and Mannen H 2014 UTS2R gene polymorphisms are associated with fatty acid composition in Japanese beef cattle Animal Sci. J. 85(5) 499–505
[9] Erimbetov K T 2006 Regulation of protein metabolism and qualities of products of growing animals Current problems of biology in livestock production (Mater. of the IV Conf.) (Borovsk) pp 38–9
[10] Zolev S and Dzhavalov A K 2011 Influence of antioxidant medicine on the content of phospholipids in blood plasma of calves Problems of biology of productive animals: Sci. Theoret. J. 2 51–4
[11] Kolganov A V, Kalnitsky B D and Niyazov N S-A 2010 Influence of protein consumption level, its amino-acid structure and additives of some amino acids on lipid exchange of farm and laboratory animals Problems of biology of productive animals: Sci. Theoret. J. 4 41–54
[12] Karcagi R G, Gaál T, Wágner L and Husvétl F 2008 Effect of various fat supplementations on liver lipid and glycogen of high-yielding dairy cows in the peripartal period Acta Veterinaria Hungarica 56(1) 57–70
[13] Gardan D, Gondret F and Louiveau I 2006 Lipid metabolism and secretory function of porcine intramuscular adipocytes compared with subcutaneous and perirenal adipocytes Am. J. Phisiol. Endocrinol. Metab. 291 E372–E380
[14] Cómoze-Cortés P, Hervás G and Fuente M A 2007 Effect of supplementation of dairy ewes diet with olive oil on milk fatty acid profile, animal performance and in vitro rumen fermentation From Sci. to Applications-Innovations for a better World (Mater. of 5th Euro Fed Lipid Cong. and 24th Sympos. of the Nordic Lipidforum, Oils, Fats and Lipids) 198 p
[15] Logachev K, Karimov I, Duskaev G, Frolov A, Tulebaev S and Zav’yalov O 2015 Study of Intercellular Interaction of Ruminal Microorganisms of Beef Cattle Asian J. of Animal Sci. 9 248–53
[16] Escudero N L, Zirulnik F, Gomez N N, Mucciarell S I and Materes M S 2006 Influence of a protein concentrate from Amaranthus cruentus seeds on lipid metabolism Exp. Biol. Med. 231 50–9
[17] Salvatori G et al 2008 Lipid composition of meat and backfat from Casertana purebred and crossbred pigs reared outdoors Meat Sci. 80 623–31
[18] Aliev A A and Martynushov V M 1974 Transformation of main fatty acids in the course of their intake into a lymph. Lipids in the organism of animals and humans (Moscow: Nauka) pp 3–10
[19] Efremov A N and Kharchenko L N 1992 Metabolism of high-molecular fatty acids in the organism of highly productive sheep. Technology and economy of sheep breeding (Stavropol: VNIIOOK) pp 34–41
[20] Pokrovsky A A 1979 Metabolic aspects of pharmacology and toxicology of food (Moscow: Medicine) pp 183