Morphological characteristics of Aberdeen-Angus cows and heifers in relation to polymorphisms C528T and C73T of leptin gene

A N Ruchay1, 2, 3, K M Dzhulamanov1, N P Gerasimov1 and V I Kolpakov1

1 Federal Research Centre of Biological Systems and Agro-technologies of the Russian Academy of Sciences, 29, 9 Yanvarya Str., Orenburg, 460000, Russia
2 Department of Mathematics, Chelyabinsk State University, Bratiev Kashirinykh 129, Chelyabinsk, 454001, Russia
3 South Ural State University (National Research University), Lenin prospekt 76, Chelyabinsk, 454080, Russia

E-mail: vkolpakov056@yandex.ru

Abstract. Animals breeding with a strong constitution and good adaptability to the environmental and forage conditions of rearing zone is crucial (or critical) in increasing meat productivity. The aim of our research was the morphological characteristics of Aberdeen Angus cows and heifers in relation to C528T and C73T polymorphisms of leptin gene. The objects of the study were cows after the first calving (n = 50) and heifers at the age of 20 months (n = 49), which were grouped by the genotype for leptin gene and polymorphisms C528T and C73T. Genetic variability of Aberdeen-Angus cows and heifers by leptin gene was associated with the morphological characteristics of the mature herd. The LEP C528T polymorphism in heifers had a significantly greater effect on the variability of live weight and body size. The heterozygous variant was more preferable for selection and breeding work aimed at increasing the massiveness and size of meat herds.

1. Introduction

The productive quality of beef cattle is very closely related to body size and (body) conformation type. An increase in growth rate and live weight are the main requirements for a perspective type of beef cattle. At the same time, the production of heavier carcasses is ensured due to the interconnection of these qualities [1]. The popularity of tall breeds and types of animals is increasing in the world, and selection work with British beef breeds is carried out in the direction of creating rather large, elongated individuals in body format, characterized by pronouncedly developed muscles, not inclined to early fat accumulation. Generally, faster growth means better feed utilization for muscle building. The meat animals breeding with a strong constitution and good adaptability to the environmental and forage conditions of the reared zone is crucial (or critical) in increasing beef productivity [2]. A fairly complete picture of typicality and direction of animals’ productivity is provided by the division of physique into the leptosomal (narrow-bodied with long limbs) and eirisomal (broad-bodied with short limbs) types. Leptosomal type animals are characterized by a narrow skeletal structure, insufficient development of latitudinal measurements, small chest girth, thin and long muscles. Eirisomy is accompanied by a general massiveness of the body (broadness), rounded shape, excessive development of fat tissue,
enlarged chest girth and voluminous abdomen [3]. An important task of improving selection and breeding work is to identify candidate genes, in which the nucleotide polymorphism is reliably associated with phenotypic variability of animals [4]. Leptin is a hormone that plays an important role in metabolism, regulates the accumulation of body fat, as well as the weight and linear growth of animals, the physique development, the function of immune and reproductive systems [5].

The aim of the paper was to assess the morphological characteristics of Aberdeen Angus cows and heifers in relation to the C528T and C73T polymorphisms of leptin gene.

2. Materials and methods
Cows after first calving (n = 50) and heifers at the age of 20 months (n = 49) were grouped by the genotype for polymorphism C528T [6] and C73T [7] in leptin gene.

The method for determining body types is based on calculating the deviations of body build indices (wide-chest and wide-rump) of an individual from the corresponding extreme variants found in the population [8].

Formulas for calculating body build indices:

\[
\text{Index of widechest} = \frac{\text{Chest width}}{\text{Chest girth}} \times 100; \\
\text{Index of widerump} = \frac{\text{Hip width}}{\text{Chest girth}} \times 100.
\]

Body type constituents were calculated using the formula:

\[
\text{Constituent for widechest} = \frac{Wc_{\text{max}} - Wc_{i}}{Wc_{\text{max}} - Wc_{\text{min}}} \times 100,
\]

where \(Wc_{\text{max}}\) and \(Wc_{\text{min}}\) – the maximum and minimum values of the wide-chest index in the population, respectively.

The constituents for wide-chest index were calculated in a similar way. The value of body type constituent is varied in the range from 0 to 100. The constituents were assigned to a certain type depending on their size in accordance with the scale (table 1).

### Table 1. The scale of constituents distribution by the body type.

| Body type constituent | The value of constituent | The type of constituent |
|-----------------------|--------------------------|------------------------|
| Wide-chest            | 0-49.9                   | Eirisomal              |
|                       | 50.0-100.0               | Leptosomal             |
| Wide-rump             | 0-49.9                   | Eirisomal              |
|                       | 50.0-100.0               | Leptosomal             |

The method of differentiating animals by type is based on the analysis of two constituents’ combination according to body build indices. A total of 4 body types were distinguished considering all possible combinations of two constituents: eirisomal, eiri-leptosomal, leptosomal and lepto-eirisomal.

Data were processed by the methods of basic statistics using the Microsoft Office “Excel 10.0” and the specialized program “Statistica 10” (“Stat Soft Inc.”, USA). The statistical difference between the mean values were assessed by the "Tukey's test for unequal N" method. Values at \(P \leq 0.05\) were considered valid.

3. Results
The impact of polymorphisms in different positions of leptin gene on the variability of weight and linear growth was established when studying the morphological characteristics of Aberdeen-Angus heifers (table 2). However, a single nucleotide substitution at LEP C528T position had a greater effect on the variability of exterior parameters in young animals. Thus, individuals carrying the heterozygous genotype C528T were distinguished by the largest size and massiveness. They surpassed their peers in absolutely all parameters of weight and linear growth. The most significant differences were found
between carriers of the CT and CC genotypes: the difference of live weight was 31.8 kg (6.03%; \( P < 0.05 \)), withers height - 4.2 cm (3.42%; \( P < 0.01 \)), hip height - 4.7 cm (3.71%; \( P < 0.01 \)), hip width - 3.8 cm (8.90%; \( P < 0.05 \)), hip joint width - 4.4 cm (9.63%; \( P < 0.05 \)), backside halfgirth - 5.8 cm (5.53%; \( P < 0.05 \)), wide-rump index - 1.0% (\( P < 0.05 \)). Thus, heterozygous young animals were characterized by better development in height and in back third of the body. Heifers with TT genotype of LEP C528T polymorphism were characterized by intermediate expression of live weight, body volume, and linear measurements.

**Table 2.** Morphological characteristics of Aberdeen-Angus heifers in relation to polymorphisms C528T and C73T of leptin gene.

| Indicator                      | LEP C528T | LEP C73T |
|--------------------------------|-----------|----------|
|                                | CC        | CT       | TT       | CC        | CT       | TT       |
| N. heads                       | 13        | 24       | 12       | 13        | 24       | 12       |
| Live weight, kg                | 527.6±5.94\(^a\) | 559.4±8.11\(^b\) | 541.8±5.67 | 545.0±7.42 | 554.1±8.55 | 539.9±9.36 |
| Body volume, m\(^3\)           | 0.38±0.016 | 0.45±0.017 | 0.42±0.015 | 0.41±0.015 | 0.44±0.018 | 0.41±0.024 |
| Linear measurements, cm        |           |          |          |           |          |          |
| Withers height                 | 122.8±0.84\(^b\) | 127.0±0.75\(^a\) | 125.8±0.68 | 125.7±0.78 | 126.5±0.72 | 124.4±1.18 |
| Hip height                     | 126.6±1.01\(^b\) | 131.3±0.82\(^b\) | 129.4±0.77 | 129.8±0.83 | 130.4±0.84 | 128.5±1.32 |
| Oblique length of the body      | 135.5±0.84 | 138.8±0.99 | 137.2±0.65 | 137.2±0.79 | 138.4±1.06 | 137.0±1.22 |
| Chest width                    | 41.7±0.81  | 44.6±0.71 | 43.5±0.71 | 43.2±0.70 | 44.5±0.73 | 42.9±1.02 |
| Chest depth                    | 64.0±0.98  | 67.5±0.91 | 65.8±0.91 | 65.5±0.92 | 67.5±0.86 | 65.3±1.28 |
| Chest girth                    | 167.7±2.19 | 175.8±1.98 | 172.3±1.96 | 171.8±1.96 | 175.5±1.96 | 170.9±2.84 |
| Hip width                      | 42.7±0.83\(^a\) | 46.5±0.92\(^a\) | 45.3±0.86 | 44.9±0.83 | 46.1±1.00 | 44.6±1.23 |
| Hip joint width                | 45.7±0.87\(^a\) | 50.1±1.07\(^a\) | 48.6±0.98 | 47.9±0.95 | 49.9±1.07 | 47.8±1.44 |
| Backside halfgirth             | 104.9±1.29\(^a\) | 110.7±1.41\(^a\) | 108.9±1.32 | 108.4±1.25 | 109.9±1.56 | 107.8±1.88 |
| Metacarpus girth               | 18.7±0.17  | 19.6±0.23 | 19.1±0.29 | 19.2±0.25 | 19.5±0.26 | 19.0±0.28 |
| Body build indices, %          |           |          |          |           |          |          |
| Wide-chest                     | 24.8±0.16  | 25.3±0.12 | 25.2±0.14 | 25.1±0.13 | 25.3±0.14 | 25.1±0.18 |
| Wide-rump                      | 25.4±0.24\(^a\) | 26.4±0.24\(^a\) | 26.3±0.22 | 26.1±0.20 | 26.2±0.30 | 26.0±0.31 |
| Density                        | 123.7±0.89 | 126.6±0.60 | 125.6±0.96 | 125.2±0.80 | 126.8±0.58 | 124.7±0.98 |

The C73T polymorphism of leptin gene had a much smaller effect on the exterior formation in heifers. Data analysis showed that heterozygous carriers outperformed their peers in weight and linear growth. The TT genotype was associated with minimal development of body weight and size.

Similar studies were carried out in the herd of Aberdeen-Angus cows (table 3). More expressed differences in the exterior formation were found in animals' distribution by genetic variants of LEP C528T polymorphism. In this connection, the minimum indicators were recorded in TT genotype carriers. They were characterized by a higher body density with a smaller body size and live weight.

The heterozygous genotype (CT) was distinguished by its relative height-growth and better development of back third of the body from its peers. Thus, the trend observed in the study of body formation in heifers' group was repeated in mature herd.

Single-nucleotide polymorphism in position of the second exon of leptin gene (LEP C73T) also contributed to the variability of the exterior parameters in cows. Thus, animals with CC genotype were superior in most linear measurements to their peers, and the greatest difference was found with the alternative homozygous TT variant. The most expressed differences were recorded in the hip height - 1.5 cm (1.15%), chest width - 1.2 cm (2.70%), chest depth - 2.4 cm (3.59%), chest girth - 4.5 cm (2.57%), backside halfgirth - 2.3 cm (2.07%). The superiority in these measurements provided the C73TT\(^cc\) genotype carriers with a maximum body volume of 0.48 m\(^3\), which exceeded the corresponding indicator
of their peers by 0.02-0.03 m³ (4.35-6.67%).

Table 3. Morphological characteristics of Aberdeen-Angus cows in relation to polymorphisms C528T and C73T of leptin gene.

| Indicator                      | LEP C528T | LEP C73T |
|-------------------------------|-----------|----------|
|                               | CC        | CT       | TT       | CC        | CT       | TT       |
| N, heads                      | 24        | 20       | 6        | 6         | 22       | 22       |
| Live weight, kg               | 646.9±16.37 | 645.1±22.16 | 608.1±49.21 | 647.6±62.26 | 648.3±21.12 | 633.0±13.93 |
| Body volume, m³               | 0.46±0.017 | 0.46±0.020 | 0.44±0.037 | 0.48±0.050 | 0.46±0.018 | 0.45±0.016 |

Linear measurements, cm

| Withers height                | 128.1±0.83 | 129.5±1.16 | 126.0±2.21 | 129.0±3.18 | 128.7±0.95 | 128.0±0.90 |
| Hip height                    | 131.2±0.92 | 132.3±1.29 | 129.5±2.22 | 132.5±3.28 | 131.6±1.03 | 131.0±1.00 |
| Oblique length of the body    | 140.0±0.93 | 139.3±1.19 | 138.0±2.24 | 139.8±2.99 | 139.7±1.03 | 139.1±0.95 |
| Chest width                   | 44.8±0.63  | 45.1±0.71  | 44.2±1.68  | 45.7±1.99  | 45.1±0.60  | 44.5±0.66  |
| Chest depth                   | 68.1±1.14  | 67.4±1.49  | 67.2±2.50  | 69.3±3.19  | 68.1±1.36  | 66.9±1.11  |
| Chest girth                   | 176.7±2.09 | 176.2±2.62 | 174.8±5.00 | 179.3±6.25 | 177.0±2.31 | 174.8±2.10 |
| Hip width                     | 47.2±0.70  | 47.3±0.81  | 46.3±1.84  | 48.0±2.27  | 47.3±0.67  | 46.7±0.74  |
| Hip joint width               | 51.0±0.74  | 51.9±0.95  | 49.8±1.82  | 51.5±2.35  | 51.8±0.82  | 50.6±0.77  |
| Backside halfgirth            | 111.7±1.10 | 111.8±1.25 | 110.7±2.82 | 113.2±3.46 | 112.0±1.05 | 110.9±1.15 |
| Metacarpus girth              | 20.7±0.23  | 20.6±0.28  | 20.7±0.56  | 21.0±0.63  | 20.9±0.25  | 20.4±0.22  |

Body build indices, %

|                                | CC        | CT       | TT       | CC        | CT       | TT       |
|                                | 25.4±0.10 | 25.6±0.10 | 25.2±0.28 | 25.4±0.26 | 25.5±0.11 | 25.4±0.10 |
| Wide-rump                      | 26.7±0.14 | 26.8±0.16 | 26.5±0.37 | 26.7±0.41 | 26.7±0.12 | 26.7±0.17 |
| Density                        | 126.1±0.77 | 126.4±0.97 | 126.6±1.89 | 128.1±2.00 | 126.6±0.92 | 125.5±0.74 |

The genetic variability of heifers determined the differences in body type formation (figure 1).

The young animals were distributed in the following proportions: leptosomal - 57.1%, eirisomal -
30.6% and lepto-eirisomal - 12.2%. The highest proportion of leptosomal type (narrow-bodied and tall) was formed in the combined genotypes CT/CT (61.5%) and CC/TT (70.0%), respectively, according to polymorphisms C528T and C73T of leptin gene. The eirisomal type (wide-bodied and compact) was mainly formed in carriers of CT/TT (60.0%) and TT/CC (40.0%) genotypes.

The cows’ distribution by body type was significantly different from the ranking of heifers (figure 2).

Figure 2. Distribution of Aberdeen-Angus cows by body type depending on C528T and C73T polymorphism of leptin gene.

Eirysomal type cows are the most common (54.0%). Also, a significant proportion were transitional forms: eiry-leptosomal (22.0%) and lepto-eirisomal (10.0%). The prevailing eirisomal type was formed in CC / CT and CT / TT haplotypes cows - 75.0 and 66.7%, respectively. A large proportion of transitional body forms was characteristic in CT / CT (50.0%), CC / TT (37.5%) and CT / TT (33.3%) complex of genotypes.

4. Conclusion
Genetic variability of Aberdeen-Angus cows and heifers for leptin gene was associated with the morphological characteristics of the mature herd. The LEP C528T polymorphism in heifers had a significantly greater effect on the variability in live weight and body size. The heterozygous variant was more preferable for selection and breeding work aimed at increasing the massiveness and size of meat herds.

Acknowledgments
The Russian Science Foundation, grant No. 21-76-20014, supported this work.

References
[1] Kolpakov V, Ruchay A, Dzhulamanov K and Gerasimov N 2020 Genotypical features of the exterior development of Hereford bull-calves E3S Web of Conferences 164 06024 DOI:10.1051/e3sconf/202016406024
[2] Dzhulamanov K M, Gerasimov N P, Ruchay A N, Kolpakov V I and Dzhulamanov E B 2019 The assessment of morphological features in Hereford cattle IOP Conf. Ser.: Earth Environ. Sci. 341 012062 DOI:10.1088/1755-1315/341/1/012062
[3] Lefler T F and Bagaev V V 2014 The exterior characteristics by the method of the body-build measurements and indexes The Bulletin of KrasGAU 9 142-6
[4] Kolpakov V I, Dzhulamanov K M and Gerasimov N P 2019 The association of polymorphism of bovine growth differentiation factor-5 gene with development of body measurements *FEBS Open Bio* **9**(S1) 97

[5] 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 Journal of Veterinary Sciences* **30**(2) 41-8 doi:10.33899/ijvs.2016.121382

[6] Nkrumah J D, Li C, Yu J, Hansen C, Keisler D H and Moore S S 2005 Polymorphism in the bovine leptin gene promoter associated with serum leptin concentration, growth, feed intake, feeding behavior, and measures of carcass merit *J. Anim. Sci.* **83**(1) 20-8 doi:10.2527/2005.83120x

[7] Buchanan F C, Fitzsimmons C J, Van Kessel A G, Thue T D, Winkelman-Sim D C and Schmutz S M 2002 Association of a missense mutation in the bovine leptin gene with carcass fat content and leptin mRNA levels *Genet Sel Evol* **34**(1) 105-16 doi:10.1051/gse:2001006

[8] Aysanov Z M 1998 Determination of body types in cows *Zootekhniya* **4** 5-8