Microstructure of muscle tissue and its connection with slaughter and meat qualities of young rams of different genotype

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Abstract. The successful development of the world sheep breeding is due to its meat productivity. In this regard, dorper meat breed gained its popularity, which has good meat qualities. The aim of the paper was to study the histological structure of the longissimus muscle of back of young rams of Kalmyk fat-tailed breeds and hybrids (1/2 Kalmyk fat-tailed + ½ dorper), as well as to establish a correlation between histological indicators of muscle tissue and slaughter and meat qualities. The work was carried out in LLC “Agrofirma Aduchi”, Republic of Kalmykia in 2016-2017. It was found that the muscle tissue of crossbred young rams was characterized by a larger number of muscle fibers per unit area, a smaller diameter of muscle fiber, a higher rating of “marbling”. The content of connective tissue was greater in purebred rams than in crossbred ones. The area of the “muscle eye” was larger in crossbred animals of the second group. In the animals of Kalmyk fat-tailed breed, the coefficient of variation in the number of muscle fibers per mm² was high and made up of 7.36 % for the overall assessment of “marbling” to 10.59 %, the content of connective tissue – 5.94 %, which is higher compared to crossbred animals. Muscle tissue of crossbreed young rams is characterized by significantly more muscle fibers per unit area, smaller diameter of muscle fiber, and a higher rating of “marbling”.

1. Introduction

The successful development of the world sheep breeding and its competitiveness are largely caused by the increased attention, first of all, to its meat productivity [1]. One of the effective methods of increasing the production of mutton and improving its quality is the crossing of ewes with rams of meat and manically breeds [2].

Mutton is one of the most valuable types of meat products and is in high demand in the world market. In meat sheep breeding, the main focus is on the production of lamb meat and young lamb, making up 90 percent and more of the total cost of production in this industry, of which up to 80% is obtained through the sale of lambs of the current year of birth. Specialization of sheep breeding in meat production allows to increase its economic efficiency and ensure stable development [3, 4, 5].

In this regard, there is a great interest in improving the meat productivity of sheep based on the use of available pedigree gene pool of meat breeds of sheep, the creation of new more productive, well adaptive to local climatic and technological conditions of their breeding [6, 7, 8]. Therefore, it is
necessary to improve the genetic resources of sheep with precocity and high meat productivity. In this regard, gained its popularity meat breed dorper [9, 10, 11].

Dorper breed sheep were brought to the Republic of Kalmykia in 2016. In Russia, this breed is new and data on its use when crossing with other breeds a little. Therefore, the study of the efficiency of crossing this breed with domestic breeds of sheep is an urgent problem.

Along with this, there is increasing interest in the formation of high meat productivity of sheep and especially to its qualitative characteristics.

It is known that the most valued “marble” meat, as it has special taste qualities thanks to intramuscular fat, evenly distributed in the form of fat layers between muscle fibers. This figure depends on the diameter of the muscle fibers and the amount of connective tissue.

In this regard, the aim of our study was to investigate the histological structure of the longissimus muscle of back of young rams of Kalmyk fat-tailed breed and hybrids (1/2 Kalmyk fat-tailed × ½ dorper), as well as to establish a correlation between histological indicators of muscle tissue and slaughter and meat qualities.

2. Material and method of the study

Scientific and production experience was carried out in LLC “Agrofirma Aduchi” in 2017-2018 according to the scheme presented in table 1.

| Group       | Breed                |
|-------------|----------------------|
| I–control   | Kalmyk fat-tailed    |
| II– experimental | Kalmyk fat-tailed Dorper |

Two groups (40 heads in each) of ewes Kalmyk fat-tailed breeds on the principle of pair of counterparts were formed for the experiment. Ewes in group I were covered with rams of Kalmyk fat-tailed breed, and the ewes of group II by rams dorper breed (experimental group). Lambing of ewes occurred in April 2017.

To study the meat qualities of experimental young rams, a control of slaughter-experimental young rams at the age of 8 months was carried out. Three heads were killed from each group. During the slaughtering, samples of the longissimus back muscle were taken from each carcass, freed from fat and connective tissue membranes, in the area between the 9-12 thoracic vertebrae. The assessment of nutritional and energy value of meat products has driven by the chemical composition of the average sample mass of meat, in addition taking an average sample of longissimus back muscles, fat-fat–tailed.

The coefficient of ripeness of the meat content was determined by the ratio of dry matter to moisture, expressed as a percentage.

The caloric value of meat by the formula: 

\[ (Km) = (39.77 \times F) + (23.86 \times P), \]

where 1g of fat (F) – 39.77 kJ, 1g of protein (P) – 23.86 kJ. For histological studies, muscle tissue samples were fixed with 10% formalin. Histological studies were performed according to the standard technique in the laboratory of morphology and product quality of All-Russian research Institute of sheep and goat breeding – branch of Federal State Budgetary Scientific Institution “North Caucasus Federal Scientific Agrarian Center”.

3. Results of the study

Meat is one of the main sources of protein and fat. However, in addition to proteins and fats, meat contains minerals, carbohydrates (glycogen) and moisture, as well as vitamins, enzymes, etc.

The chemical composition of meat cannot be constant, as it depends on many factors, such as: breed, age, sex, feeding conditions and content, as well as individual development of the animal.

It is believed that the value of meat is largely determined by the content of its basic elements-proteins, fats and carbohydrates, which determine the taste, smell, as well as energy value.
Energy value, or in other words caloric value – is the amount of energy released in the body from food during digestion.

In food, relatively low-fat, high-protein meat is of increasing interest. Previously, it was thought that meat in which the ratio of protein and fat in terms of calories was close to one is more valuable. However, recently, the demand of the population has increased for lean meat, in which the fat content does not exceed 10 -12 %.

Ash indicates the content of minerals included in the chemical structure of food products, as well as present in food products as a result of their introduction from the external environment.

Comparative analysis of the chemical composition of meat revealed some differences depending on the genotype (table 2).

The main indicator of the quality of meat from the standpoint of its chemical composition is protein.

Chemical analysis of the longissimus back muscle revealed certain differences in the percentage of moisture and protein.

**Table 2.** Chemical composition and caloric content of the longissimus back muscle of young sheep at the age of 8 months (n=3).

| Indicator                        | Group                        |
|---------------------------------|------------------------------|
|                                 | I - control                  | II – experimental           |
| Moisture, %                     | 7.2±0.35                     | 76.97±0.42                  |
| Dry matter, %                   | 21.78±0.35                   | 23.03±0.42                  |
| Protein, %                      | 18.67±0.27                   | 19.90±0.32                  |
| Fat, %                          | 2.23±0.49                    | 2.20±0.44                   |
| Ash, %                          | 0.88±0.07                    | 0.93±0.06                   |
| The coefficient of ripeness, %  | 27.84±0.58                   | 29.92±0.71                  |
| Calories, kJ                     | 534.21±16.99                 | 562.31±14.73               |
| Ratio: moisture / protein       | 4.19±0.06                    | 3.87±0.07                  |
| Protein/dry matter              | 0.86±0.02                    | 0.86±0.02                  |
| Protein/fat                     | 8.37±1.75                    | 9.04±2.06                  |

The dry matter content of the longissimus back muscle was greater in crossbreeds of the second group by 1.25 abs. %, and moisture respectively less on 1.25 abs. %.

Crossbred young rams had a high protein content, and significantly outperformed peers of the control group by 1.23 abs. % (P>0.95).

In terms of mineral content (ash), the differences between the groups were insignificant.

The table data shows that animals of the experimental groups were of rather high indices of the coefficients of ripeness. The young rams of the experimental group exceeded the animals of the control group by 2.08 %.

It was found that the energy value of crossbred meat was higher by 28.1 kJ than that of purebred.

Increased accumulation of dry matter in meat and higher ratios of dry matter to moisture are reliable values indicating increased precocity of the animals being evaluated.

Fat determines the energy value of meat. However, its excess reduces the quality of meat, breaking the ratio of protein and fat, increases the cost of production of mutton, as its formation is spent much more energy feeds than per unit of muscle tissue growth.

Along with the study of the chemical composition of the longissimus back muscle, the chemical composition of the average sample of meat was also studied (table 3).
Table 3. Chemical composition of average sample of meat of young rams (n=3).

| Indicator                | Group                      | I - control          | II – experimental |
|--------------------------|----------------------------|----------------------|-------------------|
| Moisture, %              |                            | 72.07±1.48           | 71.23±0.55        |
| Dry matter, %            |                            | 27.93±1.48           | 28.77±0.55        |
| Protein, %               |                            | 18.37±0.64           | 18.60±0.30        |
| Fat, %                   |                            | 8.53±1.18            | 9.17±0.78         |
| Ash, %                   |                            | 1.03±0.03            | 1.00±0.06         |
| Calcium, g/kg            |                            | 0.06±0.01            | 0.057±0.01        |
| Phosphorus, in terms of P₂O₅, % |                        | 0.09±0.01            | 0.087±0.01        |
| Vitamin E, mg/100g       |                            | 0.35±0.07            | 0.32±0.02         |
| Calories, kJ             |                            | 777.59±53.90         | 808.35±24.97      |
| The coefficient of ripeness, % |                        | 38.75±2.89           | 40.39±1.10        |
| Ratio: moisture / protein|                            | 3.92±0.21            | 3.83±0.04         |
| Protein/dry matter       |                            | 0.65±0.03            | 0.65±0.0          |
| Protein/fat              |                            | 2.15±0.26            | 2.03±0.21         |

It was found that the average meat sample contained less protein than in the longissimus back muscle in the first group of young rams by 0.3 abs.% and in animals of the second group on 1.3 abs.%, and the fat content was higher by 6.27 and 6.97 abs.%, respectively.

The average sample of meat of crossbreeds of the second group contained on 0.23 abs. % more protein and on 0.64 abs. % of fat than peers of the first group.

As a result, the meat of crossbred young rams is more caloric than the meat of purebred ones, the difference was 30.76 kJ.

In terms of calcium, phosphorus, vitamin E, the differences between the groups were insignificant and statistically unreliable.

The ratio of dry matter to moisture (ripeness coefficient) was higher in crossbred sheep by 1.52% than in purebred peers of the control group.

One of the important qualitative indicators of meat is its moisture-binding capacity. From the ability of meat to retain or bind water depends on its properties such as juiciness, tenderness, loss in heat treatment, presentation, technological advantages.

In this regard, in recent years, much attention is paid to the study of the relationship of chemical synthesis with its physical and chemical properties, in particular, with the moisture-binding capacity, depending on many factors.

Moisture holding capacity is the difference between the moisture content of the mass of meat and the amount of moisture separated during heat treatment.

The ability of meat to be stored for a long time is largely due to the pH value, which in turn depends on the amount of glycogen in the muscles of animals.

Our findings suggest some differences between the experimental young rams.

Physical and chemical quality indicators of the average sample of young ramp meat are presented in table 4.

Table 4. Physical and chemical parameters of the average sample of young ramps meat after fattening.

| Indicator                        | Group                      |
|----------------------------------|----------------------------|
| Water-holding capacity, %        | I - control                | II - experimental       |
| Hydrogen ion concentration (pH), units | 51.15±0.15                   | 54.02±0.159            |
| Acid number, mg KOH / g fat      | 0.24±0.03                  | 0.29±0.018             |
| Peroxide number, mol / kg        | 0.4±0.1                    | 0.43±0.067             |

Our studies found that the meat of crossbred young rams of the second group was characterized by a greater moisture-holding capacity and exceeded that by 2.87 % (P>0.999). The acidity of meat in
animals of experimental groups was approximately at the same level of 5.93-5.97 units, which characterizes good quality of meat. As for the acid number, the crossbred animals differed slightly more in this indicator, but the difference was statistically unreliable. No statistically significant differences between the experimental groups were established for the peroxide number either.

The results of histostructural analysis of meat of experimental young rams are presented in table 5.

| Indicators                        | Group   |
|----------------------------------|---------|
|                                  | I - control | II - experimental |
| Number of muscle fibers per mm², PCs. | 403.95±17.172 | 439.9±8.699 |
| Diameter of muscle fiber, µm      | 30.76±0.235  | 27.63±0.533  |
| Overall assessment of “marbling”, point | 26.51±1.62   | 28.48±0.81   |
| Connective tissue content, %      | 8.47±0.291   | 7.73±0.133   |
| ”Muscle eye” area, cm²             | 18.94±0.17   | 22.49±0.251  |

Our studies found that the muscle tissue of crossbred sheep was characterized by a large number of muscle fibers per unit area by 10.88%, a smaller diameter of muscle fiber by 3.13 microns (P>0.99), a higher rating of “marbling” by 1.97 points. Content of connective tissue was more than purebred young rams, than crossbred on 0.74 abs. percent (figures 1, 2).

As for the area of the “muscular eye” (cross section of the longissimus back muscle), which indirectly determines the content of meat in the carcass, this figure was higher in crossbred animals of the second group by 3.55 cm² (P>0.999).

Zootechnical science distinguishes between hereditary and non-hereditary variability. Hereditary variability is associated with the genotype of animals, such variability is transmitted from parents to posterity. Non-hereditary variability is not related to the genotype of animals with their carriers of hereditary inclinations, so it cannot be transmitted to posterity during sexual reproduction.

In our studies, we took into account hereditary variability, which has a genetic nature, so we tried to create identical optimal conditions for animals, for a more reliable manifestation of their genotype.

To calculate the variability of features, there are several methods, but it is most convenient to use the coefficient of variability Cv in relative terms, as a percentage.

The results of our studies showed that in animals of the Kalmyk fat-tailed breed the coefficient of variability in the number of muscle fibers per mm² was high and made up of 7.36 %, by the total assessment “marbling” – 10.59 %, the content of connective tissue – 5.94 %, which is higher compared to crossbred animals respectively by 3.93 abs.%, 5.67%, 2.95%.

Crossbred animals of the second group had a greater coefficient of variability in the diameter of the muscle fiber by 2.02 % and meat content by 0.38% compared to purebred young rams.

Low variability was observed in muscle fiber diameter and meat in purebred young sheep– 1.32% and 1.56%, and in crossbreed – 3.34% and 1.94%, respectively. Also, hybrids have a low rate of variability in the content of connective tissue-2.99%.
Purebred animals of the Kalmyk fat-tailed breed have a high coefficient of variation for the studied indications, therefore the possibility of selection and improvement for specified indications in the breed is very high.

As known, one of the ways to establish the relationship between economic and useful qualities is to conduct a correlation analysis (table 6).

For many years in the process of evolution of the animal organism was formed into a single complex controlled system, parts of which interact directly connected with each other.

In breeding practice, phenotypic and genotypic correlative links between economic and useful features are widely used.
The law of correlation, which was formulated in 1836 by J. Cuvier and developed by C. Darwin in his doctrine of correlative variability is of great importance for effective breeding work. The use of this law in practice makes it possible under the selection by the one feature to influence the change of the other.

Correlations can be both positive (the degrees of their systems are stronger the greater the value \( r \) approaches to \( \pm 1 \)) and negative (where \( r \) is closer to -1). If \( r = 0 \), there is no correlation.

The study of correlations between the features is a necessary condition for conducting effective selection work, as it makes it possible to select one or more features, to anticipate changes in some features in the selection of others, as well as to study the causal relationship between the features. Positive and negative correlations depend on the direction of selection, feeding conditions and animal maintenance. Significant differences in the size and nature of correlations between the features were established.

Numerous studies on the study of correlations have been carried out in sheep breeding. The results of these works give a fairly definite idea of the relationship between the most important economic and useful features in sheep. Although different correlation values are obtained between the same characteristics due to different quality of sheep, different livestock, etc.

Of course, the creation of optimal selection for each of the economically useful features is difficult. Purposeful selection should be preceded by modeling the selection of different intensities for one or more features. However, selection of animals for the one feature is more effective than selection on a complex of features.

It is known that the variability of numbering features (their phenotypic diversity) is due to genetic diversity, adaptive action of genes and communication between each other and the action of different non genetic factors (age, season, feeding conditions and maintenance, etc.) that cause the paratypical variability of features.

The presence of phenotypic diversity of the population is a prerequisite for selection, at the same time, the success of selection depends largely on the genetic conditionality of the feature, the share of influence of genetic factors on the value of the feature of the posterity.

### Table 6. Correlation between meat qualities and histological parameters of the longissimus back muscle.

| Group | Number of muscle fibers per mm², PCs. | Diameter of muscle fiber, µm | Overall assessment of “marbling”, point | Connective tissue content, % | “Muscle eye” area, cm² |
|-------|--------------------------------------|------------------------------|----------------------------------------|-----------------------------|----------------------|
|       | Pre-slaughter live weight, kg        |                              |                                        |                             |                      |
| I     | -0.580±0.81                         | 0.313±0.95                  | 0.166±0.99                            | -0.857±0.51                | 0.810±0.59           |
| II    | -0.919±0.39                         | 0.949±0.31                  | -0.776±0.63                           | 0.925±0.38                 | 0.769±0.64           |
|       | Slaughter yield, %                  |                              |                                        |                             |                      |
| I     | -0.735±0.68                         | 0.903±0.43                  | 0.957±0.29                            | 0.619±0.78                 | -0.68±0.73           |
| II    | -0.936±0.35                         | 0.934±0.36                  | -0.746±0.67                           | 0.906±0.42                 | 0.739±0.67           |
|       | Chilled carcass weight, kg           |                              |                                        |                             |                      |
| I     | -0.895±0.45                         | 0.987±0.16                  | 0.999±0.01                            | 0.376±0.93                 | -0.45±0.89           |
| II    | -0.920±0.39                         | 0.948±0.32                  | -0.774±0.63                           | 0.924±0.38                 | 0.767±0.64           |
|       | Weight of internal fat, kg           |                              |                                        |                             |                      |
| I     | 0.152±0.99                          | 0.147±0.99                  | 0.295±0.95                            | 0.997±0.07                 | -0.98±0.16           |
| II    | -0.998±0.06                         | 0.706±0.71                  | -0.408±0.91                           | 0.655±0.75                 | 0.399±0.92           |
|       | Slaughter weight, kg                 |                              |                                        |                             |                      |
| I     | -0.867±0.50                         | 0.976±0.22                  | 0.998±0.07                            | 0.429±0.90                 | -0.50±0.86           |
| II    | -0.925±0.38                         | 0.944±0.33                  | -0.765±0.64                           | 0.919±0.39                 | 0.759±0.65           |
|       | Carcass weight, kg                   |                              |                                        |                             |                      |
| I     | -0.896±0.44                         | 0.987±0.15                  | 0.999±0.01                            | 0.372±0.93                 | -0.45±0.89           |
| II    | -0.919±0.39                         | 0.949±0.31                  | -0.775±0.63                           | 0.925±0.38                 | 0.769±0.64           |
Meat content weight, kg

|   | I       | II      | 1       | II      |
|---|---------|---------|---------|---------|
| I | -0.983±0.18 | 0.993±0.11 | 0.965±0.26 | 0.108±0.99 | 0.193±0.98 |
| II| -0.876±0.48 | 0.976±0.22 | -0.834±0.55 | 0.958±0.29 | 0.828±0.56 |

Weight of bones, cartilage and tendons, kg

|   | I       | II      | 1       | II      |
|---|---------|---------|---------|---------|
| I | -0.362±0.93 | 0.622±0.78 | 0.733±0.68 | 0.901±0.43 | -0.935±0.35 |
| II| -0.998±0.05 | 0.783±0.62 | -0.510±0.86 | 0.737±0.67 | 0.502±0.86 |

Meat and bone ratio

|   | I       | II      | 1       | II      |
|---|---------|---------|---------|---------|
| I | -0.443±0.90 | 0.157±0.99 | 0.006±0.10 | -0.928±0.37 | 0.893±0.45 |
| II| 0.334±0.94 | 0.375±0.93 | -0.680±0.73 | 0.440±0.90 | 0.687±0.73 |

A high negative correlation in the first and second groups between the number of muscle fibers and pre-slaughter weight (-0.580 and – 0.919), slaughter yield (-0.735 and – 0.936), mass of chilled carcass (-0.895 and – 0.920), slaughter weight (-0.867 and – 0.925), carcass weight (-0.896 and – 0.919), weight of meat content (-0.983 and -0.876), weight of bones, cartilage and tendons (-0.362 and -0.998).

A positive correlation was established between the diameter of muscle fibers and all indicators of slaughter and meat qualities.

In purebred animals of the Kalmyk breed of the first group there was a positive correlation between the overall assessment of “marbling” and all indicators of slaughter and meat qualities, and in crossbreeds of the second group on the same indicators there was a negative correlation.

Connective tissue is positively correlated in animals of first and second groups with the slaughter yield, weight of chilled carcasses, slaughter weight, carcass weight, weight of meat content and bone mass, cartilage and tendons. A negative correlation was found in animals of the first group in the content of connective tissue to the pre-slaughter mass and to the meat and bone ratio.

Crossbred animals have established a positive correlation between the area of “muscle eye” and all indicators of slaughter and meat indicators, and in purebred animals of the first group, it was revealed a negative relationship between the area of “muscle eye” and slaughter yield, weight of chilled carcass, a mass of internal fat, slaughter weight, carcass weight, weight of meat content, weight of bones, cartilage and tendons.

4. Discussion

Numerous studies have found that not every combination of breeds when crossing gives a positive result. Despite the fact that earlier it was found that by crossing ewes of the Kalmyk fat-tailed breed with rams of breed dorper the effect of heterosis appears, expressed in increasing energy of growth of the fetus in the embryonic period and crossbred young sheep in the postembryonic development period on live weight, average daily and relative gains [5]. At the same time, it was necessary to study the quality indicators of meat, as they set the price of the product on the market. Histological studies give the most complete characterization of the quality of muscle tissue. Our research has found that the muscle tissue of crossbred young rams has the best quality.

We propose to use the specialized meat breed Dorper to increase the meat productivity of the Kalmyk fat-tailed sheep and to improve the quality of the meat, and on this basis to create an inbreeding type.

The creation of a highly productive type of meat sheep will increase the productivity of animals and profitability of the sheep industry.

5. Conclusions

The conducted studies give grounds to conclude that crossbred animals derived from crossing ewes of the Kalmyk fat-tailed breed with rams of the dorper breed are the best indicators of the quality of muscle tissue. The average sample of meat of crossbreeds of the second group contained 0.23 abs. % more protein and 0.64 abs % more fat than purebred peers of the first group.

As a result, the meat of crossbred sheep is more caloric.
Muscle tissue of crossbreed young rams is characterized by the best microstructure of the longissimus back muscle, characterized by significantly more muscle fibers per unit of area, a smaller diameter of muscle fiber, and a higher rating of “marbling”.

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