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Genotypic Features of the Development of Muscle Groups and Individual Muscles of Purebred and Crossbred Bulls

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Abstract

This paper comparatively examines the genotypic features of the development of muscle groups and individual muscles of the carcass of purebred Simmental bulls, and bulls crossbred with Simmentals: ½Simmental×½Red Steppe and ½Simmental×½Black and White bulls at the age of 18 months. It was found that in terms of the absolute mass of individual muscles of the spinal column, the highest level of parameters was characteristic of the bulls of group III, except for m. multifidus, where the biggest mass was shown by group I. The smallest mass, both of individual muscles, and in the group as a whole, was observed in crossbred bulls of group II. The analysis of the development of individual muscles of the shoulder girdle indicates that purebred bulls of group I exceeded the bulls in groups II and III in terms of the mass of m. brachiocephalicus, m. serratus ventralis, and m. pectoralis profundus. The bulls of group III were characterized by an advantage over the bulls of group II in the mass of m. pectoralis profundus, m. serratus ventralis, and m. brachiocephalicus. A comparative assessment of the development of individual muscles of the thoracic limb indicates that crossbred bulls of group III were distinguished by an advantage over the bulls of groups I and II. The differences in the mass of both individual muscles and between groups I and II were significant. A similar pattern of intergroup differences manifested itself in the development of both individual muscles and the pelvic limb as a whole.

Keywords: Bulls, Genotype, Muscle, Topography, Carcass, Slaughter

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Introduction

The increased productivity of cattle meat is associated with increased muscle tissue mass (Nagdalian *et al*., 2020; Solarczyk *et al*., 2020). Hence, studying the growth characteristics of the muscles of young animals of various genotypes is of considerable practical and scientific interest. Knowledge of the patterns of development and growth of muscle tissue makes it possible to more objectively determine the level of meat productivity of young animals by the age of slaughter, since the nutritional advantages and structure of muscles that play various roles in the body are not the same, and the relative growth rate of individual muscles is also different. In this regard, a detailed study of individual muscles, their dynamics of development, and growth nature are important for the correct evaluation of the meat quality of the studied genotypes (Filipčík *et al*., 2020; Randhawa *et al*., 2021).

Materials and Methods

For a comparative study of the development of muscle tissue of young animals of the studied genotypes, three groups of bulls were formed: group I that included purebred bulls of the Simmental breed; group II that included hybrids of ½ Simmental × ½ Red Steppe variety; and group III that included hybrids of ½ Simmental × ½ black and white variety. Young animals of all groups up to one and a half years of age were intensively reared with year-round stall keeping in the conditions of a standard feedlot. When the bulls reached 18 months of age, a control slaughter of three animals from each group was done according to the experimental scheme according to the method of the All-Union Academy of Agricultural Sciences (VASKHNIL), All-Russian Animal Husbandry Institute (VIZH), and All-Russian Research Institute of the Meat Industry (VNIIMP). At the same time, the slaughter qualities of young animals were taken into account, characterized by the following indicators: pre-slaughter weight, the weight of fresh carcasses, carcass yield, the mass of internal fat (raw, slaughter weight, slaughter yield) (Croué *et al*., 2017).

Since when cutting the carcass, the integrity of the soft tissues is not damaged, the left half of the carcass was dissected, and its right half was subjected to normal deboning. The carcasses were prepared under the guidelines. Muscles were separately weighed on a scale with a 1g accuracy. After preparation, all muscles were

identified according to International Veterinary Anatomical Nomenclature (Zelenevskaya, 2003). For the convenience of analyzing the material obtained, the muscles were grouped according to the characteristics of the relevant joints and the topographic location according to the scheme proposed by Levantin (1966), Glagolev and Ippolitova (1969), Berg and Butterfield (1976) and Nikitchenko (1986).

The muscles were assigned to the following groups: *group I included muscles of the spinal column*: m. multifidus, m. psoas major, m. psoas minor, m. spelenius, m. spinalis et semispinalis thoracis et cervicis, m. semispinalis capitis, m. longissimus dorsi; *group II included muscles connecting the shoulder girdle with the body*: m. pectoralis profundus, m. serratus ventralis, m. latissimus dorsi, m. rhomboideus, m.trapezius, m. brachiocephalicus; *group III included muscles of the thoracic limb:*

a) belonging to the scapula area: m. supraspinatus, m. subscapularis; b) belonging to the shoulder area: m. triceps brachii, m. biceps brachii; and *group IV included muscles of the pelvic limb:* a) belonging to the pelvic girdle area: m. gluteus medius, m. adductor femoris, m. psoas iliacus, m. gluteus profundus; b) including the thigh area: m. quadriceps femoris, m. pectineus, m. biceps femoris, m. semimembranosus, m. semitendinosus, m. tensor fasciae latae, m. gracilis, m. quadratus lumborum, m. sartoris, c) belonging to the shin area: m. gastrocnemius.

The development and growth of muscle were studied in terms of the parameters of the absolute mass of muscle groups and individual muscles in a comparative aspect, both within individual muscle groups and between the indicators of muscle mass of the compared genotypes.

Results and Discussion

An analysis of the development of individual muscles of the spinal column, regardless of the genotype, indicates that the main share in the total muscle mass is occupied by m. longissimus dorsi and the group of m. semispinalis dorsi, m. spinalis dorsi, m. spinalis cervicis, m. spinalis capitis, m. semispinalis cervicis, and m. semispinalis capitis **(Table 1)**.

The muscle mass parameters of m. semispinalis capitis and m. spinalis et semispinalis dorsi et cervicis are very close in terms of the value of the muscle mass parameters, which occupy the second and third places in the group of their localization (Ciecierska *et al*., 2020).

The smallest mass in this group was observed in m. psoas minor.

Comparative analysis of intergroup differences in the absolute mass of individual muscles of the spinal column indicates that the highest level of parameters was observed in the bulls of group III, except for m. multifidus, where the advantage was observed in the bulls of group I. At the same time, the smallest mass, both of individual muscles, and in the group as a whole, was observed in crossbred bulls of group II.

Table 1. Mass of individual muscles of the spinal column, g (X ± Sx)

Individual muscles	Group		
	I	II	III
1	2	3	4
M. longissimus dorsi	5,651±144.33	5,108±150.28	5,813±194.51
M. semispinalis capitis	1,809±66.48	1,161±35.77	1,859±77.25
M. spinalis et semispinalis dorsi et cervicis	1,800±56.17	1,418±50.31	1,838±61.97
M. longissimus capitis, m. longissimus cervicis	1,316±37.25	1,143±25.93	1,379±39.43
M. spelenius	1,125±27.54	1,006±65.20	1,207±70.08
M. psoas minor	416±16.33	370±22.83	445±32.35
M. psoas major	1,252±83.56	1,125±53.95	1,296±142.68
M. multifidus	1,558±177.90	1,014±67.52	1,307±41.39
Total for the group	14,927±179.82	12,372±339.54	15,144±388.77

Thus, cross-breed bulls of group III exceeded the bulls of groups I and II, respectively: in the mass of m. longissimus dorsi by 162-705 g (2.79-12.13%); in the mass of m. semispinalis capitis by 50-698 g (2.70-37.55%); in the mass of m. spinalis and semispinalis dorsi et cervicis by 38-420 g (2.07-22.85%); in the mass of m. longissimus capitis and cervicis by 63-236 g (4.57-17.11%); in the mass of m. spelenius by 82-64 g (6.79-5.30%); in the mass of m. psoas minor by 29-75 g (6.52-16.85%); and in the mass of m. psoas major by 44-171 g (3.40-13.19%).

At the same time, the advantage of the bulls of group I in terms of the mass of m. multifidus over the bulls in group II amounted to 544 g (34.92%), and over the bulls in group III to 251 g (16.11%). However, group III hybrids exceeded the bulls of group II by 293g (22.42%).

In general, in terms of the total mass of the muscles of the spinal column, the general pattern of intergroup differences was preserved. Therefore, the advantage of the bulls of group III over the bulls of groups I and II was 217-2,772 g (1.43-18.30%).

Analysis of the development of individual muscles of the shoulder girdle, regardless of the genotype, indicates that the main proportion in the total muscle mass is occupied by m. serratus ventralis, followed by m. pectoralis profundus **(Table 2)**.

M. rhomboideus had the smallest mass in this group.

Muscles including m. pectoralis superficialis, m. largissimus dorsi, m. trapezius and m. brachiocephalicus were characterized by very similar parameters of growth and development of the muscles of this anatomical section of the half carcass. Nevertheless, intergroup differences in the parameters of the mass of muscle groups and individual muscles, despite some similarities, are manifested. Thus, the advantage of purebred bulls of group I over the bulls of groups II and group III, respectively, amounted to 529-187 g (14.26-5.04%) in the mass of m. pectoralis profundus.

Table 2. Development of shoulder girdle's individual muscles, g (X ± Sx)

Name of individual muscles	Group		
	I	II	III
1	2	3	4
M. pectoralis profundus	3,709±91.80	3,180±171.16	3,522±77.65
M. pectoralis superficialis	1,377±53.34	948±40.23	1,608±59.37
M. serratus ventralis	5,016±138.59	4,438±112.95	5,006±144.31
M. largissimus dorsi	1,954±41.36	1,800±46.20	2,407±38.19
M. rhomboideus	596±23.65	494±25.03	1,125±48.17
M. trapezius	1,404±54.32	965±79.39	1,912±62.17
M. brachiocephalicus	1,594±40.77	912±32.14	1,451±48.36
Total for the group	15,650±364.56	12,737±501.17	17,031±604.21

10-578 g (11.52-0.2%) in the mass of m. serratus ventralis; 53-682 g (3.32-42.78%) in the mass of m. brachiocephalicus. At the same time, the bulls of group III surpassed the bulls of group II, respectively: in the mass of m. pectoralis profundus by 342 g (9.71%); in the mass of m. serratus ventralis by 568 g (11.35%); by weight m. brachiocephalicus by 539g (37.15%).

At the same time, the hybrid bulls of group III surpassed the bulls of groups I and II in terms of the mass of m. pectoralis superficialis by 231-660 g (14.37-41.04%); in the mass of m. latissimus dorsi by 453-607 g (18.82-25.22%); in the mass of m. rhomboideus by 529-631 g (446.90-56.09%); in the mass of m. trapezius by 508-947 g (26.57-49.53%) At the same time, the crossbred bulls of group II were inferior to the purebred bulls of the Simmental breed, respectively: in terms of the mass of m. pectoralis superficialis by 429g (31.15%); in the mass of m. latissimus dorsi by 154 g (7.88%); in the mass of m. rhomboideus by 102 g (17.11%); in the mass of m. trapezius by 439 g (31.27%).

A similar pattern of intergroup differences was observed in the value of the final indicators of muscle mass. Thus, the bulls of group III surpassed the bulls of groups I and II by 1,381-4,294 g (8.11-25.21%). Also, the bulls of group II were inferior to the bulls of group I by 2,913 g (18.6%).

As can be seen from the results of the analysis of quantitative indicators characterizing the development and growth of the muscles of the shoulder girdle of purebred and crossbred bulls, the variability in the manifestation of signs is obvious and does not fully fit into the logical understanding and justification of the results.

Comparative assessment of the development of individual muscles of the thoracic limb indicates that among the considered muscles in the experimental young animals of all genotypes, the muscle group of the scapula region predominates in absolute mass **(Table 3)**. At the same time, in bulls of all groups, m. infraspinatus was distinguished by the greatest mass, m. supraspinatus was the smallest mass, and m. subscapularis occupied an intermediate position.

Table 3. Development of individual muscles of the thoracic limb

Individual muscles	Group		
	I	II	
1	2	3	4
M. supraspinatus	1,342±100.17	1,530±83.52	1,532±73.71
M. infraspinatus	2,450±110.32	1,836±129.32	2,798±103.69
M. subscapularis	1,530±90.36	1,368±84.10	1,748±111.19
Muscles of the scapular area, total	5,322±150.28	4,734±103.89	6,078±238.13

M. triceps brachii	3,340±138.35	2,874±141.52	3,814±190.50
M. biceps brachii	770±59.66	952±61.38	880±38.03
Muscles of the shoulder area, total	4,110±188.93	3,826±86.42	4,694±176.75
Total for the group	9,432±347.65	8,560±276.27	10,772±377.15

It can be seen from the above data that in this group, the greatest mass of m. supraspinatus was characteristic of hybrid bulls, and purebred bulls were inferior to them by 190 g (12.4%). As for the mass of m. infraspinatus, the greatest indicator was observed in the crossbred bulls of group III. Their advantage over the bulls in groups I and II was 348-962 g (12.44-34.38%). A similar pattern manifested itself in the mass of m. subscapularis, which predetermines the parameters of differences in the following proportions amounting to 218-380 g (12.47-21.74%).

It should be noted that if in the mass of m. supraspinatus, purebred bulls of the Simmental breed were inferior to the bulls of group II by 188 g (12.29%), then in the mass of m. infraspinatus and m. subscapularis, on the contrary, they exceeded them by 614 g (25.06%) and 162 g (10.59%).

In general, in the area of the scapula, the intergroup differences in absolute and relative indicators were 756-1,344 g (12.44-22.12%).

A tendency similar to the differences in indicators between groups from the scapular area was also manifested in the final indicators of differences between genotypes in the shoulder area, but with some features of diversity in the parameters of individual muscles. Thus, in terms of the mass of m. triceps brachii the greatest indicator of mass was characteristic of crossbred bulls of group III that surpassed the bulls in groups I and II by 474-940 g (12.43-24.65%). Also, the bulls of group II were inferior to the bulls of group I by 466 g (13.95%).

In the mass of m. biceps brachii, the largest mass was observed in the crossbred bulls of group II that exceeded the bulls in groups I and III by 182-72 g (19.12-7.56%). At the same time, the young animals of group I in this indicator were inferior to the bulls of group III by 110 g (12.50%).

In terms of the total mass of the muscles of the shoulder region, the bulls of group III exceeded the bulls in groups I and II by 584-832 g (12.44-17.72%). Moreover, the animals of group II were inferior to the purebred bulls by 284 g (6.91%).

In general, in terms of the total mass of the muscles of the thoracic limb, crossbred bulls of group III demonstrated the largest weight and exceeded the bulls in groups I and II by 1,340-868 g (28.55-18.49%). At the same time, the hybrid bulls of group II were inferior to the purebred bulls of group I by 872 g (9.25%).

Knowledge of the development of muscle groups and individual muscles of the pelvic limb is of great importance since in this girdle the most valuable cuts are located, such as loin, rump, and round, which make up almost a third of the mass of the entire half carcass. The musculature of the pelvic limb is divided into three main groups: the pelvic girdle area, the thigh area, and the shin. The most significant muscles of these groups constitute about 95% of the mass of the pelvic limb.

Our results indicate that in young animals of the experimental groups, regardless of the genotype, the main part of muscles is concentrated topographically in the thigh, the pelvis, and, to a lesser extent, the shin. Moreover, bulls of different genotypes show noticeable differences in the ratios between these muscle groups. Thus, the mass of muscles in the area of the pelvic girdle in the bulls of group I was 20.43%, in group II 24.00%, in group III 23.75%; respectively, in the thigh area, it was 73.10%, 70.04%, and 70.25% and in the shin area 6.47%, 5.76%, and 6.00% **(Table 4)**.

Comparative analysis of the development of individual muscles of the pelvic limb indicates that among the muscles taken into account in the experimental young animals of all genotypes, the unequal nature of the formation of both muscle groups and individual muscles at the site of localization is manifested. Thus, in terms of the mass of m. gluteus profundus, the greatest indicator was observed in the crossbred bulls of group III and exceeded the bulls in groups I and II by 353-109 g (38.71-11.95%), in terms of the mass of m. lumboiliacus by 310-126 g (29.25-11.89%), and in weight of m. gluteus medius by 1,165-422g (27.76-10.06%). At the same time, young animals of group I in terms of the mass of the noted muscles were inferior to the bulls of group II, respectively by 244 g (30.3%); 184 g (19.70%); and 743 g (19.68%). A somewhat different pattern of intergroup differences in this area was manifested in the mass of m. adductor. Moreover, the advantage of group III bulls over bulls of groups I and II also remained within 153-278 g (6.54-11.89%), but in this variation, bulls of group I were not inferior to bulls of group II, as noted earlier, but, on the contrary, exceeded them for 125 g (5.72%).

In general, in the area of the pelvic girdle, the final indicator retained the general pattern of differences. Thus, the young animals of group III demonstrated the highest value of the indicator and surpassed the bulls of groups I and II by 1,981-935 g (23.29-10.99%). At the same time, the bulls of group I were inferior to the bulls of group II by 1,046 g (13.81%).

Table 4. Development of individual pelvic limb muscles

Name of individual muscles	**Group**		
	I	**II**	**III**
1	2	3	4

M. gluteus profundus	559±23.80	803±26.59	912±32.58
M. lumboiliacus	750±22.19	934±95.58	1,060±113.38
M. adductor	2,185±97.66	2,060±90.39	2,338±121.95
M. gluteus medius	3,032±124.74	3,775±148.61	4,197±180.36
Muscles of the pelvic girdle area, total	6,526±198.53	7,572±234.75	8,507±166.30
M. pectineus	513±45.16	489±21.50	555±40.10
M. quadriceps femoris	5,046±237.20	5,516±323.79	6,263±366.88
M. biceps femoris	5,913±285.32	5,752±270.34	6,530±340.07
M. semimembranosus	6,054±413.47	5,019±196.44	5,698±165.98
M. semitendinosus	2,628±139.32	2,540±174.08	2,884±97.65
M. gracilis	1,155±58.85	1,161±63.06	1,318±117.56
M. tensor fasciae latae femoris	1,219±86.83	912±64.72	1,036±50.90
M. sartorius	344±32.10	327±21.37	372±38.18
M. gluteofemoralis accessorius	473±33.14	445±38.21	505±48.56
Muscles of the thigh area, total	23,345±555.90	22,161±390.14	25,160±718.48
Including the shin area — m. gastrocnemius	2,065±78.35	1,816±45.76	2,150±55.43
Muscles of the pelvic limb, total	31,936±1134.15	31,549±985.70	35,817±1072.15

Analyzing the degree of development of individual muscles of the thigh area, it should be noted that generally, for most of their mass parameters, a certain pattern of intergroup differences can be traced. Moreover, in this area, except for m. semimembranosus and m. tensor fasciae latae femoris, the highest mass indicators were demonstrated by crossbred bulls of group III. Thus, the bulls of group III exceeded the bulls of groups I and II in weight of m. pectineus by 42-66 g (7.57-11.89%); m. quadriceps femoris by 1217-747 g (19.43-11.93%); m. biceps femoris by 617-778 g (9.45-11.91%); m. semitendinosus by 256-344 g (8.88-11.93%); m. gracilis by 163-157 g (12.37-11.91%); m. sartorius by 28-45 g (7.53-12.10%); m. gluteofemoralis accessorius by 32-60 g (6.34-11.88%). At the same time, young animals of group I exceeded the bulls in group II in weight of m. pectineus by 24 g (4.68%); m. biceps femoris by 161 g (2.72%); m. semimembranosus by 1,035 g (17.10%); m. semitendinosus by 88 g (3.35%); m. sartorius by 17 g (4.94%). Moreover, in terms of the mass of some muscles in this area, the proportion was inverse. Thus, the bulls of group I were inferior to the bulls of group II in weight of m. quadriceps femoris by 470 g (8.52%); m. gracilis by 6 g.

We should also note separately the level of development of m. tensor fasciae latae femoris, the greatest value of which in terms of the absolute mass was demonstrated by the animals of group I. The bulls of groups II and III were inferior to them by 307-183 g (25.18-15.01%). At the same time, the bulls of group III exceeded the bulls of group II by 124 g (11.97%).

In general, according to the total indicator of the muscles of the thigh area, the greatest mass was observed in the animals of group III that exceeded the bulls of groups I and II by 1,806-2,999 g (7.18-11.92%). Also, the bulls of group II were inferior to the bulls of group I in terms of this indicator by 1,184 g (5.07%).

As for m. gastrocnemius, which is characterized by the lowest nutritional value, the intergroup differences were also standard here and corresponded to the patterns of differences between the groups noted above. Thus, the advantage of animals of group III over the bulls of groups I and II in absolute weight was 85-334 g (3.95-15.54%). Also, the bulls of group II were inferior to the bulls of group I in this indicator by 249 g (12.06%).

Conclusion

Summing up the analysis of the level of development of the muscles of the pelvic limb, it should be noted that the crossbred bulls of group III, showing the greatest weight, exceeded the bulls in groups I and II by 3,881-4,268 g (10.84-11.92%). At the same time, crossbred bulls of group II were inferior to purebred bulls of group I by 387 g (1.22%).

Analyzing the development of muscle groups and individual muscles of the carcass, it should be noted that, more generally, a certain pattern of muscle tissue formation in young animals of the studied genotypes is manifested. As can be seen from the results of a detailed analysis of the level of muscle development, the existing pattern of heterogeneity is due to the unequal growth rate of standard muscles of animals of different genotypes.

To develop programs for the real possibility of external control of the development and growth of the muscles of animals in the postnatal period of their growth and development, it is necessary to continue similar studies on other genotypes.

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