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# Characteristics of beef traits in crossbred bulls with different degrees of its marbling

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**Abstract.** The purpose of this experimental study was to characterise the quantitative and qualitative traits of beef in the most common domestic animals in Ukraine from Ukrainian Black-and-White dairy and Holstein cattle bulls at different classes of marbling severity of *m. longissimus dorsi*. Twenty-six carcasses from 20-22-month-old bulls of the farm "Zhuravushka" located in Brovary district of Kyiv region, Ukraine, served as material for the study. The marbling of *m. longissimus dorsi* was evaluated according to the JMGA standard (2000) and the morphological composition and quality characteristics of the carcasses were determined. The obtained results showed that in the medium and good (3 to 5 points) class of marbling, the marbling of the *m. longissimus dorsi* in carcasses was higher than in the unsatisfactory and below average grade (1 and 2 points), the content of muscle tissue of the second grade was 6.5 points ($P \leq 0.01$), bone – 2.5 points ($P \leq 0.01$), and the carcass conformation (meatiness) was better developed by 33.3% ($P \leq 0.01$), the development of its cover with adipose tissue – by 31.8% ($P \leq 0.05$) and muscle colour – by 10.2% ($P \leq 0.05$). At the highest (from 3 to 5 points) class of marbling of beef, the content of muscle tissue of the highest (3.9 points) and first (2.6 points) grades was significantly ($P \leq 0.05$) lower, and the size of the "muscle eye" area was 22.5% lower (the difference was not statistically significant). Accounting for the probable difference in slaughter signs depending on the marbling of beef, the data

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obtained can be used to predict the content of certain grades and quality characteristics of muscle tissue in carcasses of crossbred bulls from Ukrainian Black-and-White and Holstein dairy cattle

**Keywords:** conformation (meatiness) of carcasses; marbling of beef; meat productivity; meat characteristics; quality characteristics of carcasses

## Introduction

In an increasingly competitive meat market, beef quality is becoming a crucial factor in consumer choice and economic efficiency of production. The defining feature of beef quality in international classification systems is marbling, as it has close correlations with the sensory characteristics of meat, determining its nutritional quality (Otto *et al*., 2024). In particular, a study by T. Erena *et al*. (2024) confirmed the link between marbling, tenderness and overall taste characteristics of meat, which can be useful for the meat processing industry and product quality control. According to T. O'Quinn *et al*. (2024), beef flavour is a key driver of consumer demand and is influenced by many factors throughout the animal's life cycle and after slaughter – from marbling and genetics to cooking and storage methods.

In accordance with the marbling scales, beef quality is assessed according to the Beef Carcass Grading Standard from the Japan Meat Grading Association (JMGA, 2000) in Japan, United States Standards for Grades of Feeder Cattle (USDA, 2000) in the United States, Korea Institute for Animal Products Quality Evaluation (KAPE, 2019) in South Korea, Meat Standards Australia (MSA, 2015) in Australia. Marbling of *m. longissimus dorsi* as the main trait of beef is included in the Australian Meat Standards Index and is used in the USA to predict the expected difference in the productivity of bulls' progeny according to the Expected Progeny Difference (EPD) system. The standards of the Commission Regulation (EC, 2008) and DSTU 4673:2006 "Cattle for slaughter. Technical specifications" do not take into account the marbling of meat in Europe and Ukraine when assessing cattle carcasses. They focus on live and slaughter weights of animals. As noted by M. Gagaoua *et al*. (2020), these features do not indicate their real value. Marble inclusions in the middle of the muscles were identified by E. Cardenas *et al*. (2024) as the content of adipose tissue. The degree of marbling of beef depends on the sex of the cattle, the level of feeding, age and live weight before slaughter, and the technological process of its rearing. This creates certain economic difficulties for efficient cattle breeding. According to T. Erena *et al*. (2024), bull calves with better carcass quantitative characteristics produce worse meat quality than bullocks and heifers.

In the context of dairy cattle, a modest correlation was observed between the marbling of meat and the content of internal adipose tissue (Martín *et al*., 2022). Furthermore, O. Kruk *et al*. (2024) indicated that an increase in marbling of *m. longissimus dorsi* is associated with a reduction in the muscle tissue of the higher and first grades in beef from bull calves of the Ukrainian Black-and-White dairy breed (UBWD) at the age of 18 to 24 months. The findings of F. Drachmann *et al*. (2024) further corroborated the absence of a relationship between beef marbling and other traits. In recent years, there has been a significant increase in the demand for marbled beef in Ukraine. This is evidenced by the assessment of beef marbling in accordance with the DSTU 4673:2006 standard, which stipulates the requirements for cattle intended for slaughter. The absence of a relationship between marbling and other traits was demonstrated in the experiments of F. Drachmann *et al*. (2024). However, given that

the assessment of marbling of beef in accordance with DSTU 4673:2006 "Cattle for slaughter. Technical specifications" is not foreseen in Ukraine, it is important to establish quantitative and qualitative characteristics of carcasses at different levels of marbling in animal meat. A better understanding of this issue will help to practically prove the need to include the classification of marbling of cattle carcasses in Ukraine in regulatory documents to prove the production of quality beef in accordance with optimal standards.

Therefore, the aim of the research was to investigate the manifestation of quantitative and qualitative characteristics of beef in the carcasses of 20-22-month-old crossbred bull calves from Ukrainian Black-and-White dairy cows and Holstein bulls in accordance with the classes of marbling of muscle tissue of *m. longissimus dorsi*, which would allow to ensure optimal yield of the main components of meat to satisfy consumer demand.

## Materials and Methods

The study was carried out in 2014-2016 on bull calves (n = 26) obtained from cattle of Ukrainian Black-and-White dairy (UBWD) and Holstein (H) breeds of the farm "Zhuravushka", located in Brovary district of Kyiv region, Ukraine. After birth, the animals were kept in a group. From the age of 4 months to 20-22 months, they were raised and fattened at the farm's feedlot. The cattle's need for nutrients was satisfied by rough, juicy, green, concentrated fodder and mineral fertilisers from the farm's automated feeders. After the bull calves were slaughtered, their carcasses were weighed. The carcasses were visually assessed for conformation (meatiness) and development of adipose tissue in accordance with the Commission Regulation (EC, 2008). The conformation of the carcasses was classified on a 5-point scale: E (perfect) – all profiles are fairly convex, perfectly developed muscles (5 points); U (excellent) – all profiles are convex, very well developed muscles (4 points); R (good) – profiles are normal, well developed muscles (3 points); O (satisfactory) – profiles are weakly expressed, muscles are moderately developed (2 points); P (unsatisfactory) – all profiles are weakly expressed, muscles are poorly developed (1 point).

The development of the fat cover was classified on a 5-point scale: low – almost no fat coating (1 point); minor – slight fat coating, muscles are visible almost throughout the carcass (2 points); medium – almost the entire carcass is covered with fat, fat accumulation is in the thoracic part (3 points); high – the carcass is covered with fat, fat accumulation in the thoracic and shoulder parts (4 points); very high – the entire carcass is covered with fat without gaps, large accumulation of fat in the thoracic part (5 points).

After sawing the carcasses in half, the half carcasses were cut between the $12^{th}$ and $13^{th}$ rib. The length and depth of the "muscle eye" of *m. longissimus dorsi* were measured with a ruler. The area of the "muscle eye" was calculated in accordance with the order of the Ministry of Agrarian Policy of Ukraine No. 290 (2004) using the formula (1):

$$S = L \times D \times 0.8, \quad (1)$$

where $S$ is the area of the "muscle eye", cm 2; $L$ is the length of the "muscle eye", cm; $D$ is the depth of the "muscle eye", cm; 0.8 is the coefficient. The colour of muscle and adipose tissue was determined using a scale from 1 to 7 according to the method (JMGA, 2000). According to JMGA (2000), the degree of marbling of *m. longissimus dorsi* was assessed on a 12-point scale (Table 1). According to the marbling, carcasses (n = 9) with a marbling score of 1 to 2 points were assigned to the first group, and carcasses (n = 17) with a marbling score of 3 to 5 points were assigned to the second group. Using Microsoft Excel 2016, statistical analysis was performed to determine the arithmetic mean, its error, and the reliability criterion.

***Table 1.*** *Classification of beef marbling*

| Quality grade | Parameters of marbling degrees – BMS (beef marbling standard) |
|---|---|
| 5 – excellent | from No. 8 to No. 12 |
| 4 – good | from No. 5 to No. 7 |
| 3 – average | from No. 3 to No. 4 |
| 2 – below average | No. 2 |
| 1 – unsatisfactory | No. 1 |

**Source:** authors' development based on the data of JMGA (2000)

All the manipulations during this study were carried out taking into account the basic principles of bioethics, in accordance with the Law of Ukraine No. 3447-IV "On the Protection of Animals from Cruelty" (2006) and the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (1986).

## Results and Discussion

The assessed marbling of the beef ranged from unsatisfactory (1 point) to good (5 points). The average grade was 4 points. In carcasses with medium and good (3 to 5 points) classes of marbling of *m. longissimus dorsi*, compared to unsatisfactory and below average (1 to 2 points) marbling, such signs as the relative amount of second-grade muscle tissue by 6.5 points and bone by 2.5 points were significantly ($P \leq 0.01$) higher (Table 2). As indicated in their work E. Peña-Gonzalez *et al*. (2020), marbling (fat in the middle of the muscle) in cattle matures late. It becomes noticeable after the formation of other fat depots. According to S. Sugii *et al*. (2022), fat is first formed around the internal organs in the abdominal cavity, then under the skin, between and in the middle of the muscles (marbling).

***Table 2.*** *Indicators of carcass morphological composition in crossbred bull calves based on different marbling classes of m. longissimus dorsi, M ± m*

| Trait | Class of marbling, points | |
|---|---|---|
| | from 1 to 2 (n = 9) | from 3 to 5 (n = 17) |
| Pre-slaughter live weight, kg | 400 ± 7.3 | 410 ± 8.3 |
| Carcass weight (slaughter), kg | 184 ± 5.7 | 183 ± 3.5 |
| Slaughter yield (carcass), % | 46.0 ± 0.16 | 44.6 ± 0.11** |
| Muscle tissue, kg | 129.3 ± 4.35 | 130.9 ± 2.76 |
| Muscle tissue, % | 70.3 ± 0.71 | 71.5 ± 0.71 |
| Including higher grade, kg | 31.7 ± 2.27 | 27.0 ± 1.01 |
| Including higher grade, % | 24.5 ± 0.74 | 20.6 ± 0.65* |
| First grade, kg | 62.1 ± 2.40 | 59.4 ± 1.26 |
| First grade, % | 48.0 ± 0.54 | 45.4 ± 0.20* |
| Second grade, kg | 35.5 ± 1.54 | 44.5 ± 1.46* |
| Second grade, % | 27.5 ± 1.00 | 34.0 ± 0.77** |
| Adipose tissue, kg | 11.1 ± 1.17 | 5.2 ± 0.64* |
| Adipose tissue, % | 6.0 ± 0.19 | 2.9 ± 0.14*** |
| Tendons and ligaments, kg | 3.3 ± 0.39 | 2.1 ± 0.16 |
| Tendons and ligaments, % | 1.8 ± 0.13 | 1.2 ± 0.13* |
| Bones, kg | 40.3 ± 1.16 | 44.6 ± 0.69 |
| Bones, % | 21.9 ± 0.31 | 24.4 ± 0.27** |

**Note:** * $P \leq 0,05$; ** $P \leq 0,01$

**Source:** authors' development

The increase in the absolute and relative amount of muscle tissue classified as the second grade with better marbling development can be explained by the fact that it also includes fat located between the muscles, which was released during tenderisation. When the marbling score was 3-5 points, the slaughter yield was significantly ($P \leq 0.01$) lower (by 1.4 points). A decrease in the percentage of carcass yield with an increase in the marbling class of beef was also proven in previous studies (Greenwood, 2021). This is due to the fact that at meat processing plants, when processing beef with better marbling, processors remove excess fat deposited in the body under the skin from animals. Therefore, the increase in adipose tissue under the skin, which has a low market value, is considered waste from beef production (Yamada *et al.*, 2020).

The relative content of muscle tissue of the higher and first grades, as well as tendons and ligaments, was significantly ($P \leq 0.05$) lower by 3.9 points, 2.6 and 0.6 points, respectively, with medium and good (3 to 5 points) marbling degree. The absolute amount of adipose tissue in the carcass was 2.1 times higher ($P \leq 0.05$) with unsatisfactory and below average (1 and 2 points) degrees of marbling of *m. longissimus dorsi*. In dairy cattle, the deterioration of carcass quality traits with an increase in the degree of marbling was noted in the studies by S. Liu *et al.* (2024). Because of this, the authors believe that beef producers should not breed dairy cattle with a high content of fatty tissue in the middle of the muscles, either by genetic selection or by adjusting diets.

The average and good (3 to 5 points) class of marbling of *m. longissimus dorsi* significantly ($P \leq 0.01$) improved the conformation (meatiness) of carcasses by 33.3% compared to the unsatisfactory and below average (2 points) class of marbling (1 point) (Table 3). Evaluating the quality attributes of carcasses according to the EC Standard (2008), similar results were also obtained in the studies of L. Schulz & A. Sundrum (2020). According to their data, the correlation is stronger between beef marbling and carcass conformation than with the development of fatty tissue. The conformation of cattle carcasses is a breed factor and depends on the interaction between the genotype of the animals and their growth characteristics. With an average and good assessment (from 3 to 5 points) of the level of marbling of *m. longissimus dorsi* compared to unsatisfactory and below average (1 and 2 points), the development of fatty tissue on the carcass was significantly ($P \leq 0.05$) 31.8% higher and there was a tendency to better thickness (28.6%) of subcutaneous adipose tissue.

***Table 3.*** *Qualitative traits of bull carcasses according to different marbling classes of m. longissimus dorsi, M ± m*

| Assessment of marbling class *m. longissimus dorsi*, points | Traits | | | | | |
|---|---|---|---|---|---|---|
| | Carcass conformation, points | Development of adipose coating, points | Thickness of subcutaneous adipose tissue, cm | Colour of muscle tissue, points | Colour of fatty tissue on the carcass, points | Area of the "muscle eye", $cm^2$ |
| from 1 to 2 (n = 9) | 2.4 ± 0.13 | 2.2 ± 0.11 | 0.7 ± 0.07 | 4.9 ± 0.08 | 4.4 ± 0.18 | 88.9 ± 5.34 |
| from 3 to 5 (n = 17) | 3.2 ± 0.09** | 2.9 ± 0.21* | 0.9 ± 0.10 | 5.4 ± 0.12* | 4.6 ± 0.13 | 72.6 ± 4.99 |

**Note:** * $P \leq 0,05$; ** $P \leq 0,01$

**Source:** authors' development

The development of adipose tissue is used to classify, grade and describe the value of carcasses for the meat industry (Brito *et al.*, 2024). According to M. Ju *et al*. (2024), fatty tissue has both negative and positive effects on beef quality. It protects the carcass from moisture loss during evaporation, which leads to increased meat toughness, and is less desirable because it leads to a decrease in slaughter yield, muscle eye area, and water retention capacity of meat (Kruk *et al.*, 2024). Therefore, for high productivity and meat quality, the thickness of fatty tissue under the skin for bulls should be 8.0 mm (Zurbriggen *et al.*, 2024). In addition, the quality of meat from cattle depends not only on the amount and thickness of adipose tissue under the skin, but also on its content in the muscles, the breed of animals, growth rate, and inbreeding.

With medium and good grades (3 to 5 points) of marbling compared to unsatisfactory and below average grades, there is a tendency to reduce the area of the "muscle eye" of *m. longissimus dorsi* by 22.5%. This indicates that with more inclusions of adipose tissue in the *m. longissimus dorsi*, its growth slows down, and therefore the carcass contains less valuable edible parts, including the highest and first grade of muscle tissue. The *m. longissimus dorsi* muscle is located in sections (thoracic and lumbar) that occupy a significant proportion of the carcass.

Carcass cuts with a higher marbling content have better flavour characteristics (O'Quinn *et al.*, 2024). Therefore, due to the deterioration in the yield of valuable cuts, it is not possible to use the values of the marbling class of *m. longissimus dorsi* to predict the production of the highest and first grades of beef in the carcasses of bulls from Ukrainian dairy cows and Holstein bulls at the age of 20-22 months. The highest grade of marbling of muscle tissue was significantly ($P \leqslant 0.05$) better by 10.2% and there was a tendency to improve the colour of subcutaneous fat tissue. The colour of muscle and adipose tissue is an indicator of beef freshness. Yellow adipose tissue is negatively assessed in many countries around the world.

Thus, with the best evaluation of carcasses according to marbling classes, many quantitative and qualitative characteristics of beef, in particular the content of muscle tissue of the highest and first grades, the area of the "muscle eye" *m. longissimus dorsi*, are worse in 20-22-month-old bulls from Ukrainian Black-and-White dairy cows and Holstein bulls. Therefore, improving the quality of beef by regulating the formation of its marbling in cattle remains problematic and expensive for a number of reasons. First of all, there are no breeds in Ukraine that have an optimal intramuscular fat content (marbling). Thus, according to J. Thompson (2004), for good sensory properties, its amount in the muscles should be 15-17%.

According to S. Raza *et al*. (2019), the black Wagyu cattle breed in Japan has the highest amount of adipose tissue (over 30%) in the middle of the muscles. In Korea, the Hanwu breed ranks second in this respect. Among European breeds, Aberdeen Angus cattle have the best concentrations of intramuscular fat and sensory properties (Bureš & Barton, 2018). In Ukraine, beef from Wagyu and Hanwu cattle is not produced because they are not available. The existing Aberdeen Angus breed is not a purebred of Scottish origin, but a hybrid (Aberdeen Angus x Black and White Holstein) bred from embryos imported from the United States. As L. Mueller *et al*. (2019) found, heifers and cows have more adipose tissue in their bodies than bull calves. And scientists E. Kul *et al*. (2019) indicate that castration of bull calves increases the deposition of adipose tissue inside the muscles.

Beef from uncastrated bull calves is of poorer quality and is valued less by consumers (Terevinto *et al.*, 2020; Nechyporenko *et al.*, 2024). In Ukraine, bull calves are rated the best and heifers the worst when delivered to meat processing plants. Since bull calves are not castrated at a young age on private farms, they are hardly ever sold. Not beef, but mainly

veal, which has virtually no intramuscular fat, is sold on the markets. Marbling of beef is better in adult animals and at higher live weight, which makes it more expensive to produce (Hudson *et al.*, 2020). Animals consume 2.25 times more feed nutrients for the formation of adipose tissue than for the growth of carcass muscles. Excess energy supplied to animals in the late fattening period significantly reduces the effectiveness of feed by reducing its digestibility, increasing the amount of fat waste and worsening the efficiency of livestock management.

I. Randhawa *et al.* (2021) found that the deposition of adipose tissue in cattle muscles is promoted by feeding them concentrated feeds with a high energy content. However, when animals are raised on concentrated feed, beef has lower levels of mono- and polyunsaturated fatty acids than those fed on grass pastures. Grazing increases the content of unsaturated fatty acids in the muscles and produces various aldehydes, ketones, alcohols, esters and carboxylic acids that contribute to the flavour and extraordinary juiciness of beef. The processor does not pay the producer for the significant amount of fatty tissue removed from carcasses that are cut off at high fatness. Payment is made only for the slaughter weight (carcass). According to Y. Li *et al.* (2020), during the life of cattle, intramuscular fat reduces lipogenesis and increases the activity of the enzyme cholesterol-25 hydroxylase, which is synthesised from glucose carbon, not acetate, during intensive fattening after the accumulation of "excess" fat between the muscles.

The marbling of beef can be determined in several ways: subjectively by visual inspection, using special equipment, and by chemical analysis. Since the structure of marbling is complex and there are no clear boundaries between each class, it is almost impossible to accurately assess the content of adipose tissue in the middle of the muscles visually. The determined fat content by chemical means does not coincide with the visual assessment of marbling, as it can detect deposits of fatty inclusions that are not visible during visual examination. In live animals, the number of marbling particles in the muscle, including the percentage and their average size, can be determined by computer image analysis (Giaretta *et al.*, 2018). The use of ultrasound for this purpose requires sophisticated equipment, its periodic calibration and adherence to standardised protocols for scanning and interpreting the images.

In this regard, the question arises of further research to solve the problem of combining the quality of beef with the quality characteristics of carcasses of dairy and dairy-meat breeds, which are fed in large quantities for slaughter. In the future, researchers should focus on determining the marbling of beef using ultrasonic devices to establish links between it and carcass quality traits in beef cattle, as this will improve its visual and sensory quality. In Ukraine, research should be conducted to determine the optimal management factors for the cultivation of cattle of common breeds to achieve a compromise between the marbling of beef and its technological, sensory characteristics and chemical composition.

## Conclusions

The obtained results of the study indicated a multifaceted influence of marbling of beef on its qualitative and quantitative characteristics in crossbred bull calves. It was established that in 20-22-month-old bull calves of Ukrainian Black-and-White and Holstein dairy breeds, the marbling score ranges from unsatisfactory class (1 point) to good (5 points). At the average and good (from 3 to 5 points) classes of marbling development of *m. longissimus dorsi*, the relative content of muscle tissue of the highest (by 3.9 points) and first (by 2.6 points) grades, tendons and ligaments (by 0.6 points) was significantly ($P \leq 0.05$) lower in the carcass, and there was a tendency (by 22.5%) to deteriorate the area of the "muscle eye". With a better (3 to 5 points) assessment of the marbling

of the *longissimus dorsi* compared to classes from 1 to 2 points, the conformation (meatiness) of carcasses significantly increased by 33.3% ($P \leq 0.01$), the bone content by 2.5 points ($P \leq 0.01$), the development of fatty tissue by 31.8% ($P \leq 0.05$) and the intensity of muscle tissue colour (by 10.2%; $P \leq 0.05$). At an increased level (3-5 points) of marbling compared to its score of 1-2 points, there was a tendency to increase the thickness of the fatty layer by 28.6% and its colour by 4.5%.

Thus, achieving an optimal balance between marbling and other quality characteristics of beef is an important task for breeders and producers. In the future, Ukraine should investigate the factors that determine effective management practices for growing and fattening cattle for the production of beef that combines quantitative and qualitative traits and is attractive to buyers for marbling and justify proposals for the introduction of a national standard for carcass evaluation based on marbling to support the livestock economy.

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## Conflict of Interest

None.

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# Характеристика ознак яловичини у помісних бугайців за різної вираженості її мармуровості

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**Анотація.** Метою даного експериментального дослідження було охарактеризувати кількісні та якісні ознаки яловичини у найбільш розповсюджених в Україні помісних тварин від української чорно-рябої молочної та голштинської худоби за різного класу вираженості мармуровості *m. longissimus dorsi*. Матеріалом для проведення дослідження послужили 26 туш від 20-22-місячних бугайців фермерського господарства «Журавушка», що розташоване у Броварському районі Київської області, Україна. Оцінили мармуровість *m. longissimus dorsi* відповідно до стандарту JMGA (2000) та визначили морфологічний склад і якісні ознаки туш. Отримані результати засвідчили, що за середнього та доброго (від 3 до 5 балів) класу мармуровості продовгуватого м'яза у тушах були більшими, ніж за незадовільного та нижче середнього оцінювання (у 1 та 2 бали), вміст м'язової тканини другого сорту – на 6,5 пункта ($P \leq 0,01$), кісток – на 2,5 пункта ($P \leq 0,01$), та краще розвиненою конформацією туш (м'ясистість) на 33,3 % ($P \leq 0,01$), розвиток її покриву жировою тканиною – на 31,8 % ($P \leq 0,05$) і колір м'язів – на 10,2 % ($P \leq 0,05$). За вищого (від 3 до 5 балів) класу мармуровості яловичини у ній вірогідно ($P \leq 0,05$) меншими були вміст м'язової тканини вищого (на 3,9 пункта) і першого (на 2,6 пункта) сортів, та розмір площі «м'язового вічка» – на 22,5 % (різниця статистично не вірогідна). За урахування вірогідної різниці в ознаках забою залежно від мармуровості яловичини отримані дані можливо використовувати для прогнозування в тушах вмісту певних сортів і якісних ознак м'язової тканини у помісних бугайців від худоби молочних порід української чорно-рябої та голштинської

**Ключові слова:** конформація (м'ясистість) туш; мармуровість яловичини; м'ясна продуктивність; характеристики м'яса; якісні ознаки туш