ANIMAL SCIENCE AND FOOD TECHNOLOGY

Journal homepage: https://animalscience.com.ua/en
Animal Science and Food Technology, 15(3), 58-71
Received 11.04.2024 Revised 12.07.2024 Accepted 15.08.2024

UDC 637.5.05:636.2
DOI: 10.31548/animal.3.2024.58

Quality characteristics of beef depending on its marbling

Olga Kruk*
PhD in Agricultural Sciences
National University of Life and Environmental Sciences of Ukraine
03041, 12-V Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0001-9975-8994

Anatoliy Ugnivenko
Doctor of Agricultural Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 12-V Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0001-6278-8399

Abstract. Marbling of muscles is a valuable feature of individual cuts of cattle carcasses, but in Ukrainian breeds it remains unexplored how the content of intramuscular fat correlates with the chemical composition, carcass characteristics, and meat processability indicators important for industrial processing and production of meat products. The purpose of the study was to establish the dependence of slaughter characteristics, chemical composition, physical and technological, and sensory properties of beef on its marbling. The marbling of muscle tissue, the content of total fat and ash mass, moisture, protein, acidity (pH), and penetration were evaluated in 34 carcasses of 18-24-month-old bulls of the "Zhuravushka" farming enterprise (FE), Brovary District, Kyiv Oblast. The aroma, juiciness, tenderness and chewiness of the boiled meat were determined by 8 tasters, focusing on colour, taste and strength of the broth. The data obtained indicate that when the marbling class improved, the content of muscle tissue in the carcass was increased by 3.0 ($p > 0.99$) points, and bones by 2.0 points ($p > 0.95$). There was a tendency to increase the second grade pulp by 1.4 points, fat tissue by 1.5 points, tendons and ligaments by 0.1 points, and to improve the conformation (meatiness) of carcasses by 6.1%, the colour of muscle (by 1.9%) and fat tissue (by 2.1%). By increasing the marbling of beef, there is a tendency to reduce the muscle tissue of the highest (by 0.9 points) and first grades (by 0.2 points), water binding capacity (by 0.7 points), boiling (by 1.1), dry matter (by 2.1 points), protein (by 1.8 points) total fat content (by 0.6 points),

Suggested Citation:
Kruk, O., & Ugnivenko, A. (2024). Quality characteristics of beef depending on its marbling. *Animal Science and Food Technology*, 15(3), 58-71. doi: 10.31548/animal.3.2024.58.

*Corresponding author

penetration (by 19.8%), meat tenderness (by 3.1%), its residue after chewing (by 6.7%), taste (by 6.9%), acidity (by 2.1%). The practical significance of the study lies in the possibility of using the data obtained to sort the carcasses of Ukrainian Black-and-White dairy bulls according to their intended purpose, considering the relationship between marbling of beef and slaughter indicators, chemical and physical, technological properties, sensory characteristics of cooked meat and broth from it

Keywords: bovine cattle; meat; conformation; carcasses; sensory characteristics

Introduction

The amount of marbling inclusions in beef is identified with the fat in the middle of the *m. longissimus dorsi*. The quality of beef carcasses according to marbling scales is determined in Australia (MSA, 2015), South Korea (MFAFF, 2007), USA (USDA, 2001), Japan (JMGA, 2000), which are mainly based on visual classification systems. In Europe, carcasses are not graded according to the EUROP (2008) system, and marbling is not determined. In addition to visual classification methods, according to E. Cardenas *et al. (*2024), marbling can be determined by automatic methods, by processing digital images, the accuracy of which is quite high and reaches a degree of correspondence with a visual score of more than 88%. T. Erena *et al.* (2024) note that meat with a high level of marbling is characterised by improved sensory properties, and T. Sakowski *et al*. (2022) suggest that no factor has a more beneficial effect on beef flavour than the fat content between muscle bundles, since marbling correlates with indicators such as taste and juiciness. But marbling did not become an indicator. It varies depending on age, sex, breed, and other characteristics. Research conducted by T. Erena *et al. (*2024) on beef obtained from animals of three different breeds, showed that the muscles localised in different parts of the body differ in the level of marbling and this difference also has certain breed features, which is advisable to consider during meat quality control. There are statistical differences in meat quality between dairy and meat breeds, but they are not detected by marbling assessment (Winebold *et al*., 2024). In breeds with a high marbling potential, when fattening livestock on concentrated feed for a long period of time, marbling improves, inedible fat is deposited (visceral and subcutaneous), the number of its scraps increases, but the quality of carcasses decreases and feed costs for products increase, which negatively affects the economy of beef production, as noted by J. Albechaalany *et al.* (2024). The quality factors of meat perceived by consumers are its sensory characteristics (tenderness and taste), nutritional properties (caloric content), appearance (colour, marbling, visible amount of fat).

Beef enters the Ukrainian markets from dairy animals, with the majority of the beef coming from Ukrainian Black-and-White dairy breeds. Features of quantitative and qualitative characteristics of meat from them with different marbling have not been studied. It is the main factor that determines the sensory quality of beef (Sakowski *et al*., 2022), has a positive effect on consumers' perception of its taste and tenderness (Beck *et al*., 2022). Dairy cattle have a slight marbling of meat, and the relationship between it and fat content in the middle of the muscles and under the skin is unclear (Martín *et al.,* 2022). There was also no correlation between beef marbling and fat content under the skin (Kruk *et al.,* 2023), indicators of the values of the "loin eye" and tenderness, juiciness, taste of boiled meat (Kruk *et al.,* 2024).

According to V.F. Ozdemir *et al.* (2024), a better understanding of the relationship between these traits will help solve the problem of beef quality in dairy cattle. Therefore, it is important to provide a practical substantiation of the need to include the quality indicator of marbling of muscle tissue in the regulatory documents on the classification of beef carcasses and to determine whether marbling affects other meat traits to increase its sustainable production from dairy animals. The marbling class should also be determined to prevent shortening of muscle fibres, which leads to the rigidity of boiled beef, since fat in bulls significantly affects the texture of meat.

The purpose of the study was to evaluate the features of the chemical composition, sensory, physical, and technological properties of beef of 18-24-month-old bulls of the Ukrainian Black-and-White dairy breed at different classes of muscle tissue marbling, according to which it would be possible to provide adequate meat and fat yield and sensory characteristics for consumers.

Materials and Methods

The study was carried out on 34 carcasses of 18-24-month-old Ukrainian Black-and-White dairy bulls at the "Zhuravushka" farming enterprise (FE), Brovary district, Kyiv Oblast. During the research, all bioethical requirements for animals were met in accordance with the Law of Ukraine No. 249 (2012) and the European Convention for the Protection of Vertebrate Animals Used for Research and Other Scientific Purposes (1986). The animals were kept from birth to 4 months of age in a group. Then they were raised and fattened on the site before slaughter. The animals' feed needs were met by the farm's fodder base. From self-feeders, bulls were fed coarse, juicy, green, concentrated feed, and minerals. Cattle were slaughtered in the slaughterhouse at the Kalynivka village. The conformation of carcasses and their subcutaneous fat were visually evaluated after weighing them in accordance with the Commission Regulation system (EC, 2008). The conformation of carcasses was classified on a scale of 5 classes: from E (very high muscle development) to P (very low muscle development). For statistical analysis, they were converted to points from 1 (corresponds to P) to 5 (corresponds to E). Subcutaneous fat development was evaluated on a scale of 5 classes: from 1 (lean) to 5 (very fat). Then the carcasses were sawn in half, and the half-carcasses were divided at the level of the 12th rib. The colour of muscle and fat tissue was determined using scales from 1 to 7 according to the method (JMGA, 2000). Between the 12th and 13th ribs, the thickness of subcutaneous fat was measured with a ruler. The marbling of meat was determined according to the JMGA (2000) method on a 12-point scale (Fig. 1). According to the class, the carcasses were divided into two groups. The first group included carcasses (n = 18) with a marbling score of 1 to 6 points. The second group (n = 16) – from 7 to 12 points.

The penetration of raw meat was determined according to the method by V. Guts & O. Koval (2007) using a PMDP-type automatic penetrometer. The content of bound moisture was determined using the "press method" by the amount of water that was released from the suspension of 0.3 g of crushed meat under the action of pressing and absorbed into the filter paper, forming a wet spot. The total area of the stain that appeared under the compressed meat and the released moisture that the paper absorbed was examined with a planimeter. The area of the wet spot was determined by the difference between the total area of the spot and the occupied meat. The water-retaining capacity of meat was determined by the ratio of the content of bound water to the weight of the meat suspension.

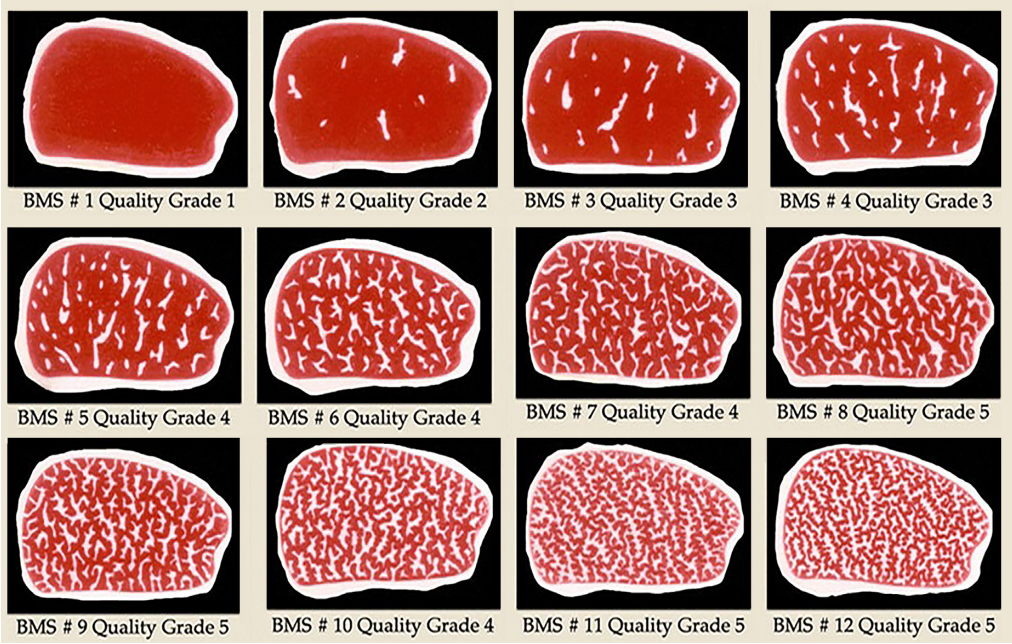

Figure 1. Marbling assessment scale for *m. longissimus dorsi*
Source: JMGA (2000)

To determine the weight of beef that remained after boiling, pieces of meat in the shape of a rectangle weighing 150 g were cut out of *m. longissimus dorsi*. They were weighed on a TNV-600 scale with an accuracy of 0.01 g and placed in a 5-litre pot and filled with 2-3 litres of cold distilled water. It was brought to a boil and the meat was cooked for 90 minutes over low heat. After cooking, the pieces were removed from the water, cooled to 20°C and weighed. Beef boiling was determined by the equation (1) provided by G. Shkurin *et al.* (2002).

$$Sm = \frac{Cm \times 100}{Rm}, \quad (1)$$

where *Sm* – amount lost in boiling of meat, %; *Cm* – weight of boiled down meat, g; *Rm* – weight of raw meat sample, g.

In the laboratory of the Department of Meat, Fish and Seafood Technology of the National University of Life and Environmental Sciences of Ukraine (NULES), the chemical composition of beef was studied in accordance with: DSTU ISO 1443:2005 (2008) – total fat content; DSTU ISO 936:2008 (2008) – total ash weight; DSTU ISO 1442:2005 (2008) – moisture content; DSTU ISO 2917:2001 (2003) – acidity (pH). The protein content was determined according to G. Shkurin *et al.* (2002).

The aroma, juiciness, tenderness, ease of chewing boiled beef and the colour, taste, strength of broth from it were evaluated by the tasting commission in the amount of 8 people in the laboratory of "Meat Quality" of the Department of Milk and Meat Production Technologies of NULES of Ukraine according to the recommendations provided by G. Shkurin *et al.* (2002). The data obtained was processed using Microsoft Excel 2016.

Results and Discussion

With an increase in the marbling class in the range from 1-6 to 7-12 points, the content of muscle tissue in the carcass increased by 3.0 points ($p > 0.99$) and in bones by 2.0 points

(p > 0.95), there was also a tendency to improve the slaughter yield (carcasses) by 0.2 points, tendons and ligaments – by 0.1 points, fat tissue – by 1.5, and muscle of the second-grade – by 1.4 points (Table 1). The improvement in the amount of muscle tissue, including second-grade muscle tissue with an increase in its marbling, can be explained by the fact that during fatty tissue fattening, it also includes the fat tissue between the muscles. Increasing the marbling class contributes to the tendency to a slight decrease in the content of muscle tissue of the highest by 0.9 points and the first grade by 2.2 points.

Table 1. *Slaughter indicators and morphological composition of bull carcasses with different marbling classes of m. longissimus dorsi, M ± m*

Indicator	Marbling class, points	
	from 1 to 6 (n = 18)	from 7 to 12 (n = 16)
Live weight after period of fasting, kg	425 ± 13.8	407 ± 7.2
Slaughter yield (carcasses), %	45.6 ± 0.31	45.8 ± 0.12
Muscle tissue, %	68.0 ± 0.68	71.0 ± 0.56**
including the highest grade, %	23.2 ± 0.88	22.3 ± 0.88
-//- first grade, %	46.7 ± 0.64	46.5 ± 0.62
-//- second grade, %	29.9 ± 1.33	31.3 ± 1.26
Fat tissue, %	2.2 ± 0.25	3.7 ± 0.53
Tendons and ligaments, %	1.5 ± 0.18	1.6 ± 0.07
Bones, %	21.7 ± 0.61	23.7 ± 0.39*

Notes: *)p>0.95; **)p>0.99

Source: developed by the authors

Deterioration of the morphological composition of carcasses at higher levels of marbling was also proved by S. Liu *et al.* (2024). In their opinion, because of this, production workers should not breed dairy cattle with a high interspersed fat between the muscles either by genetic selection methods or by adjusting diets. To solve this problem, it is necessary to understand the distribution of fat between the main fat depots: intramuscular, subcutaneous, and visceral. In most genotypes of cattle and sheep, the rate of fat accumulation intramuscularly is lower than subcutaneous and visceral, so genetic selection for a high level of marbling or using the increased energy value of the diet to deposit fat inside the muscles will result in an increase in overall fatness and feed costs.

According to the obtained data, with an increase in the marbling class, there is a tendency to a slight (by 6.1%) increase in the assessment of the conformation (fleshiness) of carcasses (Table 2). With an increase in the marbling class in points from 7 to 12, there is a tendency to worsen by 4.0% an important sign of the quality of carcasses – the development of their fat cover, compared to the marbling class from 1 to 6 points.

Table 2. *Qualitative indicators of bull carcasses depending on the marbling of muscle tissue, M ± m*

Marbling class, points	Indicators					
	conformation, points	covering of carcasses with subcutaneous fat, points	thickness of subcutaneous fat	colour of muscle tissue, points	colour of adipose tissue on the carcass, points	loin eye area, cm^2
from 1 to 6 (n = 18)	3.3 ± 0.24	2.6 ± 0.15	0.8 ± 0.10	5.2 ± 0.18	4.7 ± 0.20	79.5 ± 4.78

Table 2. Continued

Marbling class, points	Indicators					
	conformation, points	covering of carcasses with subcutaneous fat, points	thickness of subcutaneous fat	colour of muscle tissue, points	colour of adipose tissue on the carcass, points	loin eye area, cm^2
from 7 to 12 (n = 16)	3.5 ± 0.29	2.5 ± 0.19	0.8 ± 0.08	5.3 ± 0.15	4.8 ± 0.10	85.8 ± 5.65

Source: compiled by the authors

The previous study by O. Kruk *et al.* (2023), found that higher conformation indicators are observed, in particular, for better coverage of carcasses with adipose tissue. G. Brito *et al.* (2024) note that the consumer value of beef is influenced by the weight of individual cut varieties, the degree of fat content and pH, while live weight of the animal and carcass weight are important for predicting the weight of these cuts, and for determining meat yield, the importance of quantitative characteristics of subcutaneous fat thickness is important for determining the optimal slaughter age. M.S. Ju *et al.* (2024) found that subcutaneous fat on carcasses is also a negative criterion for beef quality. By protecting the carcass from evaporation, which increases the stiffness of the meat, it helps to reduce its slaughter yield. Therefore, for high productivity and quality of meat, namely, getting a brighter colour and more tender taste of beef, as recommended by G.A. Zurbriggen *et al.* (2024), so that the thickness of subcutaneous fat in bulls is 8.0 mm.

It was found that with an increase in the marbling class, there is a tendency to increase by 7.9% the area of the "loin eye" of *m. longissimus dorsi*, which is directly and significantly correlated with the carcass weight and the amount of muscle tissue, including the highest and first grades. Therefore, these authors suggest using the values of the "loin eye" to predict the amount of beef obtained and its belonging to a particular variety. With an increase in the marbling class of muscle tissue, there is a tendency to increase the rating of the beef freshness indicator – its colour – by 1.9%. With an increase in the marbling of beef, there is a tendency to improve the colour of adipose tissue by 2.1%. Thus, no significant differences were found in the qualitative characteristics of carcasses of 18-24-month-old Ukrainian Black-and-White dairy bulls with different marbling classes (Kruk *et al.*, 2024).

The results of the penetration stress determined by us show that for the marbling class of beef from 1 to 6 points in its sample, the needle of the PMDP penetrometer penetrates 19.8% deeper in 180 seconds than for a larger (from 7 to 12 points) value of its classification (Table 3). This indicates that it is more tender and juicy when marbling is worse. This can be explained by the fact that the highest class of marbling does not protect the carcass in the refrigerator from drying out and moisture loss, which is associated with a decrease in the destruction and deformation of muscle fibres.

Table 3. *Technological features of beef in different classes of its marbling, M ± m*

Marbling class, points	Indicators		
	water binding capacity, %	boiling down, %	penetration, mm
from 1 to 6 (n = 8)	63.5 ± 3.49	36.8 ± 2.53	20.6 ± 2.21
from 7 to 12 (n = 7)	52.8 ± 4.83	37.9 ± 1.92	17.2 ± 2.27

Source: compiled by the authors

With the best marbling of beef, water is retained in the meat by 10.7 points worse, which is associated with its worse suitability for storage. Because of this, its output after cooking worsens by 1.1 points. Meat losses during water runoff negatively affected the weight and output of muscle tissue of the highest and first grades – especially valuable cuts because they are located mainly in the thoracic and lumbar regions, which are the most valuable and make up a significant share of the carcass. Due to the greater loss of water from beef during heating, the proteins become tougher and less flexible, and the collagen fibrils contract. The tendency to reduce the percentage of boiling beef in the worst marbling class means an improvement in its culinary and technological properties, since this reduces the amount of waste during cooking, which reflects the economic value of meat. With an increase in the marbling of beef, there is a tendency to reduce its total fat content by 0.6 points (Table 4).

Table 4. *Chemical composition of beef at different levels of marbling, M ± m*

Marbling class, points	Indicators					
	acidity (pH)	moisture content, %	dry matter, %	protein, %	total fat content, %	total ash weight, %
from 1 to 6 (n = 8)	5.91 ± 0.189	69.7 ± 1.30	30.3 ± 1.30	21.6 ± 0.70	6.9 ± 0.97	1.9 ± 0.34
from 7 to 12 (n = 7)	5.79 ± 0.061	71.8 ± 2.35	28.2 ± 2.35	19.8 ± 1.15	6.3 ± 1.00	2.2 ± 0.51

Source: compiled by the authors

The established trend of reducing the content of intramuscular fat in beef with an improvement in its marbling was not confirmed in studies by T. Erena *et al.* (2024). That is, it seems that the marbling of beef does not affect the same qualitative feature – the amount of total fat content in meat. Marble colour is fat that is deposited between the fibres of muscle tissue, and is located between the primary and secondary muscle bundles and in their middle intramuscular. Therefore, the assessment of visual marbling is subjective and does not coincide with the fat content determined by chemical analysis, since it is possible to study fat deposits that are not noticeable by eye examination.

According to the marbling class of beef, the value of its acidity (pH) classified according to the following requirements: normal pH ⩽ 5.8; atypical >5.8pH < 6; typical pH ⩾ 6. According to the marbling of beef of the class in the range from 7 to 12 points, there is a tendency to reduce its acidity by 2.1%, that is, its normalisation (pH = 5.79). At a lower value, atypical acidity occurred (pH = 5.91). In muscle tissue, with better marbling, the pH decreases faster, which leads to a more intense passage of glycolysis and the synthesis of lactic acid. Because of this, beef remains more stable to the development of microorganisms. Normalisation of the acidity (pH) of meat by increasing its marbling, according to I. Patinho *et al.* (2024), can serve as a sign for further prediction of the sensory properties of the finished product. According to these researchers, beef at a lower pH should have an enhanced flavour in cooked beef and beef broth compared to the atypical pH that occurs at a lower marbling level.

An assessment of the consumer preferences of boiled meat indicates that with a lower class of marbling of muscle tissue, there was a tendency to increase the protein content by 1.8 points in *m. longissimus dorsi*. If there is a tendency for carcasses to have less fat, which indicates that the animals are well-fed, the findings show that they have better marbling. According to B. Santiago *et al.* (2023), who studied the effect of castration on the qualitative characteristics of carcasses in bulls and found that in

the worst body conditions, the content of proteins increases ($p \leqslant 0.05$), which are especially associated with catabolic processes (glycolysis), muscle structure and contraction, and in the best – with energy metabolism. In animals with a higher class of marbling of muscle tissue, there is a tendency to form meat with better (by 15.8%) indicators of the total weight of ash.

Thus, the assessment of beef from bulls of the Ukrainian black-and-white dairy breed aged from 18 to 24 months by marbling does not allow predicting the chemical composition depending on its value after slaughter. Elements of the chemical composition of meat vary depending on the breed of animals, their slaughter age, gender, type of muscle and adipose tissue, and methods of processing meat into products. H. Yu *et al.* (2024) investigated the influence of the breed on the market value of beef to provide new approaches to improving its quality and features of marbling and chemical composition of meat in animals of local cattle breeds. V.B. Hoa *et al.* (2023) highlighted the influence of cattle age on the chemical composition of carcasses and meat, fatty acid profiles, and genes associated with lipid metabolism. L.W. Coleman *et al.* (2023) found that meat quality varied depending on the sex of the animals, with bulls having higher acidity (pH), redder meat, and yellower fat than heifers. J.M. Vázquez-Mosquera *et al.* (2023) evaluating beef obtained from animal fattening systems with a high olein content and its effect on the subsequent composition of fatty acids that affect consumer health and found that entrecote samples show a healthier lipid fraction. E. Yarali (2023), investigating sensory analysis as one of the most common methods for evaluating food products to date, found that the way beef is processed into a finished product affects its chemical composition.

With an increase in the marbling of beef, there was a tendency to worsen by 3.2% the main component of its sensory assessment – tenderness (Table 5), which, as noted by V. Bulgaru *et al*. (2022), significantly depends on the content of soluble proteins, fats, and collagen in it.

Table 5. *Sensory properties of boiled beef at different levels of marbling, M ± m*

Marbling class, points	Sensory characteristics of boiled meat, points					
	juiciness	taste	aroma	tenderness	residue after chewing	average values for 5 tasting indicators
from 1 to 6 (n = 6)	3.4 ± 0.22	2.9 ± 0.21	3.1 ± 0.15	3.2 ± 0.30	3.2 ± 0.31	3.2 ± 0.24
from 7 to 12 (n = 7)	3.4 ± 0.15	3.1 ± ±0.09	3.1 ± 0.09	3.1 ± 0.22	3.0 ± 0.09	3.1 ± 0.14

Source: compiled by the authors

With an increase in the marbling of beef, there were no changes in its assessment by an important characteristic – juiciness, which has a positive effect on the quality of meat. Perception of tenderness and juiciness of meat reduces the content of intramuscular fat, which lubricates the fibres between the muscles worse, and does not protect beef from drying out during cooking. Juiciness in the mouth characterises the amount of juice obtained during chewing. With the highest marbling, there is a tendency to increase by 6.9% the value of such a sensory property of beef as taste. The development of taste during cooking is affected not only by the level of lipids in the middle of the muscles, but also by their composition (Albechaalany *et al.,* 2024), which are also a source of aromatic compounds important for meat quality. The aroma and taste of beef arise from the reaction of non-volatile fatty acids during heat treatment, and the type and concentration of volatile substances that are released (Ponnampalam *et al.,* 2024). Thus, an increase in the marbling of beef leads to a decrease in the total

fat content in muscles, and to a deterioration in the signs of cooked meat evaluated by tasters – tenderness and residue after chewing, and does not improve its aroma and juiciness. Consumers draw conclusions about the quality of beef only during its consumption based on the taste, tenderness and juiciness they actually perceive, confirming or refuting their pre-formed expectations based on the marbling of the meat.

Improving marbling of *m. longissimus dorsi* leads not only to a decrease in the fat content in the middle of the muscles (Table 3), but also to a slight (3.2%) deterioration in the average value of the evaluated signs of cooked meat (aroma, juiciness, tenderness, taste, residue after chewing). Bulls of the Ukrainian Black-and-White dairy breed aged 18 to 24 months with the best marbling have a mid-muscle fat content of only 6.3%, which does not affect sensory characteristics. The ambiguous relationships between sensory ratings and mid-muscle fat content may have a positive effect on the tenderness, juiciness, and taste of meat at higher parameters, which need to be substantiated for dairy animals.

Evaluating the sensory characteristics of boiled meat broth, it was found that at higher levels of marbling, there is a tendency to increase such signs of its tasting as taste and aroma (by 18.2%), and transparency (by 13.0%) (Table 6).

Table 6. *Sensory characteristics of beef broth at different marbling levels, M ± m*

Marbling class, points	Broth tasting indicators, points			
	taste and aroma	strength	transparency	average values
from 1 to 6 (n = 6)	2.2 ± 0.57	2.4 ± 0.27	2.3 ± 0.20	2.3 ± 0.19
from 7 to 12 (n = 7)	2.6 ± 0.11	2.4 ± 0.09	2.6 ± 0.20	2.6 ± 0.15

Source: compiled by the authors

With an increase in the marbling of beef, there are no changes in the strength of the broth, there is a tendency to increase its average values of tasting signs. Thus, the data obtained indicate that with an increase in the marbling class of the Ukrainian Black-and-White dairy breed from 18 to 24 months of age, only the percentage of muscle tissue ($p > 0.99$) in carcasses and the content of bones ($p > 0.95$) significantly improve, there is a tendency to increase the area of the "loin eye" and the content of muscle tissue of the second class, the conformation of carcasses. From the best class of qualitative signs of beef – marbling in animals, the yield of muscle tissue of the highest and first grades does not significantly decrease, the chemical composition of muscle tissue worsens, and the pH of muscle tissue is normalised due to glycolysis. In addition, better marbling of muscle tissue does not significantly affect the sensory characteristics of boiled beef broth.

Beef producers and its processors are interested in the quality, the carcass is determined by the marbling of muscle tissue on which its price depends on the market. Marbling, which is used to predict the initial quality of meat from cattle in Ukraine, does not have a positive effect on the sensory and culinary properties of beef, which consumers are interested in. The tenderness, taste, and juiciness of meat are based on the content of adipose tissue in the middle of the muscles. Since animals have the genetic potential to develop marbling, regardless of their feeding and maintenance, they reach the amount of it that they can develop. In beef, marbling is better formed by intensive feeding of animals with concentrated feeds with a high energy content, only after "excess" adipose tissue accumulates in the middle of the abdomen, under the skin and between the muscles. Since the quality characteristics of carcasses are more sensitive to changes in the management of animal rearing, compared to the quality of

beef, the optimal combination of them can be achieved under different conditions of feeding (Beck *et al.,* 2022) and keeping (Soulat *et al.,* 2022) livestock.

In Ukraine, there are many problems in evaluating the carcasses of Ukrainian Black-and-White dairy cattle by the marbling of beef, including the deterioration of many of its qualitative characteristics. Despite recent advances in the world regarding the possible regulation of the development of muscle tissue colour in cattle to improve the quality of beef, this problem remains insufficiently solved in Ukraine and deserves further investigation. The results of researchers show that it is possible and necessary to manage the quality of carcasses and beef through various methods of breeding, feeding and keeping animals. In this regard, the question arises of solving the problem of producing high-quality beef with high-quality characteristics of carcasses from dairy animals, which are fattened in large numbers for slaughter.

Conclusions

The best class of marbling development in the middle of the *m. longissimus dorsi* muscle of Ukrainian Black-and-White bulls aged 18-24 months affects consumer preferences and the likelihood of purchasing beef, but does not characterise its technological, sensory and culinary properties. When improving the marbling class in the carcass, only the content of muscle tissue was higher by 3.0 ($p > 0.99$), respectively, and bone – by 2.0 percentage points ($p > 0.95$). There was a tendency to increase the second grade pulp by 1.4 points, fat tissue by 1.5 points, tendons and ligaments by 0.1 points, and to improve the conformation (meatiness) of carcasses by 6.1%, the colour of muscle (by 1.9%), and fat tissue (by 2.1%). During the increase in the marbling class of beef, there was a tendency to reduce the content of muscle tissue of the highest (by 0.9 points) and first grades (by 0.2 points), water binding capacity (by 0.7 points), boiling (by 1.1) the content of dry matter in meat (by 2.1), protein (by 1.8), and total fat content (by 0.6 points). The best marbling of meat reduced its penetration (by 19.8%), tenderness (by 3.1%), meat residue after chewing (by 6.7%), taste (by 6.9%) and acidity of meat (by 2.1%), which are important technological indicators for further processing of beef and the quality characteristics of the product made from it. The increase in beef marbling did not affect the strength of the broth, but there was a tendency to improve sensory characteristics (taste and aroma) during tasting. The obtained data confirm the possibility of using beef marbling to predict the physical, technological, and tasting characteristics of meat.

In the future, research should be aimed at determining the quantitative and qualitative characteristics of beef, depending on its marbling, in livestock of other breeds of Ukraine, as this will complement the visual and sensory assessment of carcasses and meat quality. It is necessary to conduct research on the establishment of management factors for the cultivation of cattle of common breeds in Ukraine to achieve optimal marbling values and compromise with technological and sensory characteristics, and chemical composition of meat. Such data will provide consumers with additional information when choosing beef. This will become the theoretical basis for introducing the marbling index of muscle tissue into the classification system of beef carcasses in Ukraine.

Acknowledgements

None.

Conflict of Interest

None.

References

[1] Albechaalany, J., Insausti, K., & Ellies-Oury, M.P. (2024). The marbling of carcases is determined more by the characteristics of the animals themselves than by farming practices. *Italian Journal of Animal Science*, 23(1), 707-720. doi: 10.1080/1828051X.2024.2330654.

[2] Beck, P.A., Beck, M.R., & Apple, J.K. (2022). Production systems and nutrition. *Reference Module in Food Science,* 2024, 629-639. doi: 10.1016/B978-0-323-85125-1.00029-6.

[3] Brito, G., Soares de Lima, J.M., Del Campo, M., Luzardo, S., Correa, D., & Montossi, F. (2024). The implementation of grading systems for beef carcass value differentiation: The Uruguayan experience. *Animal Frontiers,* 14(2), 29-34. doi: 10.1093/af/vfae004.

[4] Bulgaru, V., Popescu, L., Netreba, N., Ghendov-Mosanu, A., & Sturza, R. (2022). Assessment of quality indices and their influence on the texture profile in the dry-aging process of beef. *Foods,* 11(10), article number 1526. doi: 10.3390/foods11101526.

[5] Cardenas, E., Tabory, E., Sanchez, A., & Kemper, G. (2024). An electronic equipment for marbling meat grade detection based on digital image processing and support vector machine. *Journal of the Saudi Society of Agricultural Sciences*, 23(7), 459-473. doi: 10.1016/j.jssas.2024.05.001.

[6] Coleman, L.W., Schreurs, N.M., Kenyon, P.R., Morris, S.T., & Hickson, R.E. (2023). Growth, carcass and meat quality characteristics of Charolais-sired steers and heifers born to Angus-cross-dairy and Angus breeding cows. *Meat Science*, 201, article number 109178. doi: 10.1016/j.meatsci.2023.109178.

[7] Commission Regulation (EC). (2008). *Commission Regulation (EC) No 1249/2008 of 10 December 2008 Laying Down Detailed Rules on the Implementation of the Community Scales for the Classification of Beef, Pig and Sheep Carcasses and the Reporting of Prices Thereof*. Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/9716803a-8887-4956-9877-629031ec7723/language-en 23.11.2018.

[8] DSTU ISO 1442:2005. (2008). *Meat and meat products. Determination of moisture content (reference method)*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=82535.

[9] DSTU ISO 1443:2005. (2008). *Meat and meat products. General specifications. Quality management systems*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=82655.

[10] DSTU ISO 2917:2001. (2003). *Meat and meat products measurement of pH (control method). Kyiv: state committee of Ukraine on technical regulation and consume policy.* Retrieved from https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=89528.

[11] DSTU ISO 936:2008. (2008). *Meat and meat products. Method of determination of mass total ash*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=89525.

[12] Erena, T., Belay, A., Hailu, D., Asefa, B.G., Geleta, M., & Deme, T. (2024). Modeling of Ethiopian beef meat marbling score using image processing for rapid meat grading. *Journal of Imaging*, 10(6), article number 130. doi: 10.3390/jimaging10060130.

[13] European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes. (1986). Retrieved from https://rm.coe.int/168007a67b.

[14] Guts, V.S., & Koval, O.A. (2007). Methods for studying the consistency of food dispersed systems by the method of penetration. *Food Industry*, 5, 16-23.

[15] Hoa, V. B., Song, D.H., Seol, K.H., Kang, S.M., Kim, H.W., Bae, I.S., Kim, E.S., Park, Y.S. & Cho, S.H. (2023). A comparative study on the carcass and meat chemical composition, and lipid-metabolism-related gene expression in Korean Hanwoo and Brindle Chikso Cattle. *Current Issues in Molecular Biology*, 45(4), 3279-3290. doi: 10.3390/cimb45040214.

[16] JMGA. Beef carcass grading standart. Japan meat grading association. (2000). Retrieved from http://surl.li/rmhqhn.

[17] Ju, M.S., Jo, Y.H., Kim, Y.R., Ghassemi Nejad, J., Lee, J.G., & Lee, H.G. (2024). Supplementation of complex natural feed additive containing (C. militaris, probiotics and red ginseng by-product) on rumen-fermentation, growth performance and carcass characteristics in Korean native steers. *Frontiers in Veterinary Science*, 10, article number 1300518. doi: 10.3389/fvets.2023.1300518.

[18] Kruk, O., Ugnivenko, A., Antoniuk, T., Kolisnyk, O., Nosevych, D., Drachuk, I., Kolesnikova, O., Zhurenko, V., Shtonda, O., & Vakulenko, V. (2023). Quality of bull beef of the Ukrainian black and white dairy breed in dependence on the development of subcutaneous fat tissue. *Potravinarstvo Slovak Journal of Food Sciences*, 17, 997-1008. doi: 10.5219/1917.

[19] Kruk, O., Ugnivenko, A., Antoniuk, T., Kolisnyk, O., Slobodyanyuk, N., Nosevych, D., Naumenko, T., & Gruntkovskyi, M. (2024). Evaluation of beef carcass quality using the muscle eye area *m. longissimus dorsi*. *Potravinarstvo Slovak Journal of Food Sciences*, 18, 619-632. doi: 10.5219/1989.

[20] Law of Ukraine No. 249 "On the Procedure for Carrying out Experiments and Experiments on Animals by Scientific Institutions". (2012, March). Retrieved from https://zakon.rada.gov.ua/laws/show/z0416-12#Text.

[21] Liu, S., Yang, Y., Luo, H., Pang, W., & Martin, G. B. (2024). Fat deposition and partitioning for meat production in cattle and sheep. *Animal Nutrition,* 17, 376-386. doi: 10.1016/j.aninu.2024.03.003.

[22] Martín, N.P., Schreurs, N.M., Morris, S.T., López-Villalobos, N., McDade, J., & Hickson, R.E. (2022). Meat quality of beef-cross-dairy cattle from Angus or Hereford sires: A case study in a pasture-based system in New Zealand. *Meat Science*, 190, article number 108840. doi: 10.1016/j.meatsci.2022.108840.

[23] Meat Standards Australia (MSA). (2015). Retrieved from https://www.mla.com.au/marketing-beef-and-lamb/meat-standards-australia/.

[24] Ministry for Food, Agriculture, Forestry, and Fisheries (MFAFF). (2007). *Processing standard for meat products act, Grading, fabrication and cutting of beef carcass*. Seoul, Korea: Ministry for Food, Agriculture, Forest and Fisheries.

[25] Ozdemir, V.F., Kocyigit, R., Yanar, M., Aydin, R., Diler, A., Palangi, V., & Lackner, M. (2024). An investigation of slaughter weight and muscle type effects on carcass fatty acid profiles and meat textural characteristics of young Holstein Friesian bulls. *Heliyon*, 10(6), 1-8. doi: 10.1016/j.heliyon.2024.e27316.

[26] Patinho, I., Cavalcante, C. L., Saldaña, E., Gagaoua, M., Behrens, J. H., & Contreras-Castillo, C.J. (2024). Assessment of beef sensory attributes and physicochemical characteristics: A comparative study of intermediate versus normal ultimate pH striploin cuts. *Food Research International*, 175, article number 113778. doi: 10.1016/j.foodres.2023.113778.

[27] Ponnampalam, E.N., Priyashantha, H., Vidanarachchi, J.K., Kiani, A., & Holman, B.W.B. (2024). Effects of nutritional factors on fat content, fatty acid composition, and sensorial properties of meat and milk from domesticated ruminants: An overview. *Animals*, 14(6), 840-879. doi: 10.3390/ani14060840.

[28] Sakowski, T., Grodkowski, G., Gołebiewski, M., Slósarz, J., Kostusiak, P., Solarczyk, P., & Puppel, K. (2022). Genetic and environmental determinants of beef quality – A review. *Frontiers in Veterinary Science,* 9, article number 819605. doi: 10.3389/fvets.2022.819605.

[29] Santiago, B., Baldassini, W., Neto, O. M., Chardulo, L. A., Torres, R., Pereira, G., Sigi, R., Chiaratti, M.R., Padilha, P., Alessandroni, L., & Gagaoua, M. (2023). Post-mortem muscle proteome of crossbred bulls and steers: Relationships with carcass and meat quality. *Journal of Proteomics,* 278, article number 104871. doi: 10.1016/j.jprot.2023.104871.

[30] Shkurin, G.T., Timchenko, O.G., & Vdovychenko, Y.V. (2002). *Slaughter qualities of cattle*. Kyiv: "Agrarian Science".

[31] Soulat, J., Picard, B., Bord, C., & Monteils, V. (2022). Characterization of four rearing managements and their influence on carcass and meat qualities in charolais heifers. *Foods*, 11(9), 1262-1284. doi: 10.3390/foods11091262.

[32] USDA. United States Standards for Grades of Feeder Cattle. (2001). Retrieved from http://www.ams.usda.gov/lsg/stand/standards/fedr-cat2000.pdf.

[33] Vázquez-Mosquera, J.M., Fernandez-Novo, A., de Mercado, E., Vázquez-Gómez, M., Gardon, J.C., Pesántez-Pacheco, J.L., Revilla-Ruiz, Á, Patrón-Collantes, R., Maria, L., Pérez-Solana, M.L., Villagrá, A., Martínez, D., Sebastián, F., Pérez-Garnelo, S.S., & Astiz, S. (2023). Beef nutritional characteristics, fat profile and blood metabolic markers from purebred Wagyu, crossbred Wagyu and crossbred European steers raised on a fattening farm in Spain. *Animals*, 13(5), 864-883. doi: 10.3390/ani13050864.

[34] Winebold, D.M., Tollefson, R.L., Deaton, C., King, A., Case, R., Robertson, J., Church, E., & Holder, A. (2024). PSV-1 A comparison of Holstein-cross cattle and beef-cross cattle in terms of performance and carcass quality. *Journal of Animal Science*, 102(2), 270-271. doi: 10.1093/jas/skae102.307.

[35] Yarali, E. (2023). Sensory analysis in meat and meat products. *International Journal of Agricultural Science*, 8, 27-37.

[36] Yu, H., Yu, S., Guo, J., Wang, J., Mei, C., Abbas Raza, S.H., Gong, C., & Zan, L. (2024). Comprehensive analysis of transcriptome and metabolome reveals regulatory mechanism of intramuscular fat content in beef cattle. *Journal of Agricultural and Food Chemistry*,72(6), 2911-2924. doi: 10.1021/acs.jafc.3c07844.

[37] Zurbriggen, G.A., Maglietti, C.S., Pouzo, L.B., Testa, M.L., Riffel, S.L., Elizalde, J.C., & Pavan, E. (2022). Extending the feeding period beyond 8.0 mm of subcutaneous fat reduces feed efficiency without improving meat colour and tenderness of non-implanted feedlot steers. *Journal of Animal and Feed Sciences,* 31(4), 360-370. doi: 10.22358/jafs/151153/2022.

Якісні ознаки яловичини залежно від її мармуровості

Ольга Крук
Кандидат сільськогосподарських наук
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 12 В, м. Київ, Україна
https://orcid.org/0000-0001-9975-8994
Анатолій Угнівенко
Доктор сільськогосподарських наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 12 В, м. Київ, Україна
https://orcid.org/0000-0001-6278-8399

Анотація. Мармуровість м'язів є цінною ознакою окремих відрубів туш великої рогатої худоби, але в українських породах залишається не дослідженим, як співвідноситься вміст внутрішньом'язового жиру із хімічним складом, ознаками туші та показниками технологічності м'яса, важливими під час промислової переробки та виробництві м'ясних продуктів. Метою роботи було встановити залежність ознак забою, хімічного складу, фізико-технологічних і сенсорних властивостей яловичини від її мармуровості. У 34 тушах 18-24 – місячних бугайців фермерського господарства (ФГ) «Журавушка» Броварського району Київської області оцінено мармуровість м'язової тканини, вміст у ній загального жиру і маси золи, вологи, протеїну, кислотність (pH), пенетрацію. У вареному м'ясі 8-м дегустаторів визначили аромат, соковитість, ніжність, легкість жування, а у бульйоні із нього колір, смак і міцність. Отримані дані свідчать, що за поліпшення класу мармуровості вміст у туші м'язової тканини був більшим на 3,0 ($P > 0,99$) пункти, а кісток на 2,0 пункти ($P > 0,95$). Проявлялася тенденція до збільшення м'якуша другого сорту на 1,4 пункти, жирової тканини – на 1,5, сухожилок і зв'язок – на 0,1 пункти, та поліпшення конформації (м'ясистості) туш на 6,1 %, кольору м'язової (на 1,9) і жирової тканин (на 2,1 %). За підвищення мармуровості яловичини проявляється тенденція до зменшення у ній м'язової тканини вищого (на 0,9 пункти) і першого сортів (на 0,2), водозв'язуючої здатності (на 0,7), уварювання (на 1,1), сухої речовини (на 2,1), протеїну (на 1,8) загального вмісту жиру (на 0,6 пункти), пенетрації (на 19,8 %), ніжності м'яса (на 3,1), залишку його після розжовування (на 6,7), смаку (на 6,9), кислотності (на 2,1 %). Практичне значення роботи полягає в можливості використання отриманих даних для сортування туш бугайців української чорно-рябої молочної породи відповідно до призначення за урахування зв'язків між мармуровістю яловичини та ознаками забою, хімічними і фізико-технологічними властивостями, сенсорними характеристиками вареного м'яса та бульйону із нього

Ключові слова: велика рогата худоба; м'ясо; конформація; туші; сенсорні характеристики