ANIMAL SCIENCE AND FOOD TECHNOLOGY

Journal homepage: https://animalscience.com.ua/en
Animal Science and Food Technology, 15(1), 42-54
Received 01.11.2023 Revised 25.01.2024 Accepted 28.02.2024

UDC 637.5:636.27(477): 637.05
DOI: 10.31548/animal.1.2024.42

Relationship between the chemical composition, physical, technological, and sensory properties of beef and the colour of muscle tissue

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. In Japan, the United States, Korea, and Australia, the colour of muscle tissue is used to assess the quality of beef carcasses, while in the EU and Ukraine, this feature is not considered. The relevance of the study was to substantiate the need to consider the colour of muscle tissue to assess the consumer properties of beef. The purpose of the study was to evaluate the chemical composition, sensory and physical, and technological properties of beef in accordance with the colour of muscle tissue. The study used carcasses of 21-month-old bulls (n=13) of Ukrainian black-and-white dairy cattle slaughtered after a 24-hour fast with free access to water in a slaughterhouse (Kalynivka village) in Brovary district of the Kyiv oblast. The colour of muscle tissue in the carcass was evaluated according to the method of the Japan Meat Grading Association. The total fat content, moisture content, and protein content of minced *m. longissimus dorsi* were analysed. Beef acidity (pH), penetration, and bound moisture content were also investigated. Consumer properties of beef were determined by tasting boiled meat (by aroma, juiciness, tenderness, ease of chewing) and broth from it (by colour, taste, thickness). It was found that the darker colour of muscle tissue had a likely (p>0.99) inverse correlation (r=-0.737) with beef boiling down. It showed a tendency for direct correlation with the cross-sectional area of back muscle (r=0.341), water binding capacity (r=0.326), penetration (r=0.295), adipose tissue colour (r=0.267), marbling (r=0.258), pH (r=0.231),

Suggested Citation:
Kruk, O., & Ugnivenko, A. (2024). Relationship between the chemical composition, physical, technological, and sensory properties of beef and the colour of muscle tissue. *Animal Science and Food Technology*, 15(1), 42-54. doi: 10.31548/animal.1.2024.42.

*Corresponding author

and inverse correlation with mineral content (r=-0.309) and overall tasting score of cooked meat (r=-0.487). There was no correlation between muscle staining and the content of moisture, dry matter, protein, and fat (r= from -0.005 to 0.094). The practical significance of the study lies in the possibility of using the acquired knowledge to sort beef carcasses according to their purpose, and consumers will be provided with additional information for objective meat selection, considering the relationship between muscle colour and sensory and physical and technological properties of beef

Keywords: meat productivity; marbling of muscles; physical; technological; and sensory properties of beef; chemical composition of meat; bovine cattle

Introduction

There are certain differences between the requirements for evaluating beef carcasses in countries with developed cattle breeding in the European Union and the world and in Ukraine. According to DSTU 4673:2006 (2011), beef is to be evaluated by live weight and carcass weight and fatness. In the European Union, cattle carcasses are evaluated according to the EUROP classification system (Commission Regulation (EC). No 1249/2008, 2008), which describes their conformation (E, U, R, O, P), external fat coverage (from 1 to 5), and its thickness. These regulations focus only on describing the yield of meat products, which weakly correlate with the nutritional value of muscle tissue at the consumer level and do not reflect the qualitative composition of carcasses and consumer satisfaction. The study by O. Kruk *et al.* (2023) proved that with a better assessment of the development of adipose tissue on carcasses according to the EUROP system, there was a tendency to reduce beef boiling and deterioration in the overall assessment of the sensory properties of cooked meat and its broth. According to the beef classification systems of the Ministry for Food, Agriculture, Forestry and Fisheries in Korea (MFAFF, 2007), Japan Meat Grading Association (JMGA, 2000), Beef Grading System in the United States (United States standards for Grades of Feeder Cattle, 2000) and Meat Standards Australia (Meat Standards Australia, 2015) there is a parallel assessment of the quality of carcasses by the colour and marbling of muscle tissue and its intended sensory and physical and technological characteristics.

For the consumer to make a decision on the purchase of meat from cattle, the most important factor (36%) is the amount of visible fat, the second place (25%) is the price, and the third (19%) is the colour (Ramanathan *et al.,* 2023). M. Hanson (2023) claims that consumers prefer beef, which has a bright "cherry-red" appearance, which they associate with the good quality of the product and consider this colour to be a criterion for freshness. Appearance defects associated with poor quality of meat and deviation from bright red towards discolouration (Pale Soft Exudativ – PSE) or darkening (Dark Firm Dry – DFD). PSE beef, which has excessive losses in water, observed in carcasses for a rapid drop in pH, and rapid metabolism in the muscles. Beef at a high (>6.09) final pH has a dark colour. Dark firm dry meat is one of the main defects in its quality associated with colour, tenderness, juiciness, taste, and shelf life. It is caused by the depletion of glycogen in the muscles and limits the synthesis of lactic acid. As a result, the pH of the muscles does not decrease enough. Meat with signs of DFD and PSE is unacceptable for consumers and leads to a decrease in the price of it or even to recycling.

According to R. Ramanathan *et al.* (2023), in the life cycle of beef production in the United States, due to colour changes, the industry annually disposes of 194.7 million kg of meat, and at the same time loses natural resources

totalling USD 3.9 billion. Referring to statistics (Maia Research Analysis), the researchers state that due to the discolouration of beef in the world in 2015-2020, losses averaged USD 14.2 billion per year. Despite the significant economic costs that are incurred for the meat industry, the decisions made by consumers regarding the purchase of beef by colour do not guarantee its nutritional quality. Colour had no significant effect on the chemical composition of bovine muscle tissue (Moloney *et al.,* 2022). To date, the academic literature in Ukraine has not discussed the relationship of colour with other beef quality indicators. Therefore, an urgent problem in the context of implementing and following European standards in the field of cattle breeding is the substantiation of the need to include the colour of muscle tissue and its other qualitative features in the regulatory documents on the classification of cattle carcasses, in order to increase the sustainability of beef production and limit the negative impact on its quality and prevent consumer diseases and reduce the loss of natural resources and energy consumed.

The purpose of the research at this stage was to evaluate the ability to predict the quality of carcasses in accordance with the colour of muscle tissue, signs of beef quality by chemical composition, sensory and physical and technological properties in bulls of Ukrainian black-and-white dairy cattle.

Materials and Methods

The study was conducted at the "Zhuravushka" farm in Brovary district of Kyiv region. From birth to the age of 4 months, the animals were kept in groups of 25 units. During the pre-weaning period, they were fed 547.2 kg of whole milk and 182.4 kg of skimmed milk. Cattle had free access to hay. It was also provided with concentrated feed at an early age. Rearing and fattening of bulls was carried out on fattening grounds with free access to feeders and water. In the farm, the animals' need for feed was provided at the expense of their own feed base. On the sites, animals were placed considering the age and live weight in the amount of up to 50 animals. Bulls had free access to coarse, juicy, green, concentrated feed and mineral supplements, which were fed from self-feeders in accordance with the diets developed on the farm. During the period from birth to reaching the age of 21 months, bulls consumed feed with a nutritional value of 34,232 MJ (Table 1).

Table 1. *Feed consumption by bulls, MJ*

Consumed	Feed								
	concentrated	fresh, total	silage	haylage	rough, total	hay	straw	green	during the growing period
MJ	6,344.0	4,894.5	3,290.7	1,603.8	4,226.6	2,951.2	1,275.4	9,645.8	34,232
%	18.5	14.3	9.6	4.7	12.3	8.6	3.7	28.3	100

Source: compiled by the authors

The pre-slaughter live weight of animals was determined by weighing them before and after 24-hour fasting with free access to water. The slaughter of 13 animals was carried out in the slaughterhouse of the "Zhuravushka" farm in the Kalynivka village. Age difference between bulls in the group was up to 5%. During the experiment, the animals were kept in accordance with the Order of the Ministry of Agrarian Policy and Food of Ukraine No. 652 (2012) and guidelines for the care and use of laboratory animals (National Research Council of the National

Academies, 2011) and acted in accordance with ARRIVE (2010) guidelines for reporting experiments on the use of live animals.

After slaughtering and skinning, the colour of muscle tissue in the carcass was visually classified according to the Japan Meat Grading Association (2000) method using a colour scale from 1 to 7 (Fig. 1), adhering to the existing regulatory document in Ukraine – "Rules of pre-slaughter veterinary inspection of animals and veterinary sanitary examination of meat and meat products" (2002).

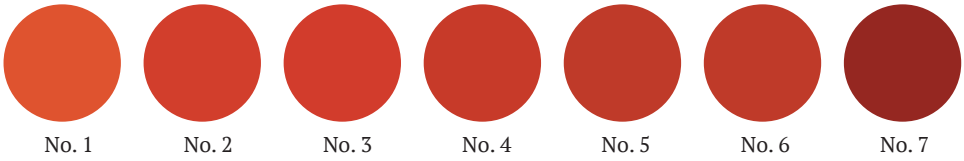

Figure 1. Muscle tissue chroma scale

Source: JMGA (2000)

After slaughtering, a piece of meat (300 g) was selected from *m. longissimus dorsi* for mincing and chemical analysis. Assessment of the total fat content in it was carried out in accordance with DSTU ISO 1443:2005 (2007), total ash content – DSTU ISO 936:2008 (2008), moisture content – DSTU ISO 1442:2005 (2008), protein (Shkurin *et al.,* 2002). The following physical and technological features of beef were also studied: acidity (pH) according to DSTU ISO 2917:2001 (2003) 48 hours after slaughter of bulls and penetration (Guts & Koval, 2007). The sensory characteristics of boiled beef (by smell, juiciness, tenderness, ease of chewing) and broth from it (by colour, taste, thickness) were evaluated by the tasting commission consisting of 8 people, and the content of bound moisture – by the "press method", in accordance with the recommendations (Antoniuk, 2020). The data obtained were processed statistically using Microsoft Excel 2016 in combination with XLSTAT. The studied indicators were evaluated by correlation coefficients calculated using appropriate methods (Osadcha, 2021).

Results and Discussion

Most carcasses are classified as grades 5 and 6 in terms of muscle colour. The chemical composition of beef was determined to assess its nutritional value. According to the study data, shown in Table 2, there was no significant correlation between muscle colour and total fat, protein, dry matter, and moisture content in *m. longissimus dorsi*. Its values (r) ranged from -0.005 to 0.094. These results are consistent with data from studies A. Diler *et al.* (2022). The researchers also found that the shade of muscle tissue in cattle is not a source of variability in their chemical composition.

Table 2. *Correlation between muscle tissue colour and chemical composition of beef*

Chemical composition	r
Moisture	-0.005
Dry matter (DM)	0.005
Protein	0.054
Total fat content	0.094
Total ash weight	-0.309
Acidity (pH)	0.231
Water binding capacity	0.326

Source: compiled by the authors

The relationship between the colour of muscle tissue and its total fat content – a key component of beef quality for consumers – was absent. Fat in the middle of the muscles gives the meat a special taste and lubricates its fibres. This improves the consumer's perception of the tenderness and juiciness of meat and gives it taste and aroma. There is a tendency for a weak positive correlation between the water content in the muscles and their colour. Water is important in the development of muscle structure and affects the quality of meat associated with taste, tenderness, and juiciness. There was a tendency for a weak direct correlation between muscle tissue colour and protein content in *m. longissimus dorsi*. According to B. Santiago *et al.* (2023), protein in muscle plays a key role in adenosine triphosphate (ATP) production, energy metabolism, oxidative stress, and redox processes in cells.

Lack of correlation between the colour of muscle tissue and the total content of fat, protein, dry matter, and moisture in *m. longissimus dorsi* indicates that it is not possible to accurately predict these elements of the chemical composition of beef by the appearance of muscles in carcasses. They depend on the prominence of meat forms in cattle (Ugnivenko *et al.,* 2023), the slaughter age of animals, the type of muscle and adipose tissue, their placement in the carcass (Diler *et al.,* 2022). When increasing the assessment of the colour of muscle tissue, there was a tendency to reverse weak correlation (r=-0.309) with the total weight of ash, whose macro- and microelements, including iron, zinc, selenium, play a crucial role in the evolution and nutrition in human health.

An increase in the colour rating of muscle tissue weakly (r=0.231) correlated with its acidity and indicated a darkening of beef with an increase in its pH. Deterioration of muscle colour due to an increase in their acidity (pH) was found by B. Santiago *et al.* (2023) also in crossbreed (½Aberdeen-Angus x ½ Charolais) animals. An increase in the colour rating of beef positively and weakly correlates with its acidity due to the fact that an increase in the pH of muscle tissue affects its physical and biochemical properties, which lead to a decrease in oxygen saturation and darkening of meat. Muscle colour is correlated with the chemical form and concentration of myoglobin contained in them (Raza *et al.*, 2019). After slaughtering animals and exsanguinating carcasses, myoglobin in muscle cells acts as a short-term oxygen reserve. The colour of meat depends not only on the content of myoglobin in the muscles, but also on the state of its oxidation. Fresh meat contains deoxymyoglobin, oximyoglobin, and metmyoglobin. Red pigmentation of beef is given by deoxymyoglobin. In the presence of oxygen, it is oxidised to oxymyoglobin and shows a bright pink-red colour. Thus, the higher the proportion of "red" muscle fibres that are rich in myoglobin due to high respiratory activity, and the fewer "white" muscle fibres, the redder the meat looks. When deoxymyoglobin and oximyoglobin are oxidised to metmyoglobin, muscle tissue becomes reddish-brown, which causes rejection in the consumer.

According to the authors of the current study, water binding capacity had a weak direct relationship (r=0.326) with an increase in muscle colour score, which indicates a slightly better ability of beef to retain moisture in this case. The water retaining ability of fresh beef determines its visual perception by the consumer, which affects their willingness to purchase the product. It also determines possible water losses during future transportation, storage, processing, and cooking of meat, and also characterises the juiciness, tenderness, and other technological properties of meat products. In raw muscle, and in unprocessed and cooked meat, the main factors determining water retention in the meat structure are the swelling that occurs in the myofibrillary structure and the forces that promote water intake or retention, and the deployment and aggregation of proteins that determine the formation of gels or

separated insoluble proteins. M. Ijaz *et al.* (2020) explained possible mechanisms of association between beef colour and other features of its quality, including water retention capacity. According to their data, typical dark firm dry beef (DFD) with a pH of more than 6.09 showed the lowest values of oximyoglobin content, which accompanied the highest values of water retention capacity and deoxymioglobin. The fact that the colour change of beef is affected by its ability to retain water is also proven by D. King *et al.* (2023). Meat becomes darker with increased water retention capacity because DFD absorbs light rather than reflects it off the surface. In order not to lead to exhaustion in the muscles of inadequate acidification and an increase in pH, which leads to darkening of beef and a decrease in its tenderness, juiciness and taste, it is necessary to carefully handle the animals during transportation to the slaughterhouse, and with raw materials after slaughter, in order to reduce the loss of water from the meat, to ensure a moderate drop in pH in the muscles of the carcass.

The physical characteristics of beef, such as fat colour, subcutaneous fat development, fat thickness, and marbling, were determined by their appearance. Manifested (Table 3) in the tendency to a direct weak correlation between an increase in the assessment class of muscle tissue colour and such physical quantities of *m. longissimus dorsi* as the cross-sectional area, penetration, marbling, and development of subcutaneous fat. Due to the increased assessment of muscle colour as a result, beef became tougher, which indicated an improbable weak direct correlation (r=0.295) between its hue and penetration – the ease with which the needle penetrated the meat.

Table 3. *Correlation between the colour of muscle tissue and the physical properties of beef*

Indicator	r
Penetration	0.295
Marbling	0.258
Subcutaneous fat thickness	-0.230
Cross-sectional area	0.341
Subcutaneous fat development	0.245
Colour of adipose tissue	0.267

Source: compiled by the authors

The background stiffness associated with connective tissue mainly depends on meat tenderness (Liu *et al.,* 2022). The stiffness of meat is increased by proteins that are present in the muscles. They protect myofibrillary proteins from destruction by proteolytic enzymes. M. Ijaz *et al.* (2020) proved that atypical DFD beef had a higher value of shear strength indicators, which were positively associated with the level of metmyoglobin, and concluded that in addition to the main acidity factor (pH), meat colour is affected by other characteristics of meat quality, including the ability to retain water, and shear strength, with a greater contribution of relative myoglobin content and glycolytic potential.

There was a tendency for a weak direct correlation (r=0.256) between the shade of muscle tissue and marbling of *m. longissimus dorsi*, which indicates that the colour of beef cannot accurately describe its good sensory properties. Marbling of muscles is the main factor determining the quality of meat (Sakowski *et al.,* 2022). Due to the strong association between marbling assessment and beef taste, the quantity and distribution in m. longissimus dorsi is a critical criterion for evaluating carcasses in the USDA and JMGA classification systems. This can also serve

as a theoretical basis for introducing the marbling indicator into the classification system of cattle carcasses in Ukraine.

There was a tendency to weak correlation (r=-0.230) between the colour of muscle tissue and the thickness of subcutaneous fat, which led to faster cooling of carcasses and caused the loss of beef tenderness. Subcutaneous fat protects the carcass from weathering and loss of moisture, which ensures juiciness of the finished meat product. With the worst thickness of fat cover, bulls increased catabolic processes (glycolysis), oxidative stress, muscle structure and contraction, which affected the colour of meat. A tendency for a weak direct correlation (r=0.341) between the shade of muscle tissue and the cross-sectional area of *m. longissimus dorsi* indicates that the colour of beef is not possible to accurately judge the content of valuable cuts in carcasses. With an improved assessment of beef colour, there is a tendency for a slightly better correlation (r=0.245) with the development of subcutaneous fat. A.P. Moloney *et al.* (2022) found that there is no or inverse relationship between the colour of muscle and adipose tissue. According to the study, there was a tendency to a weak positive relationship (r=0.267) between these traits due to a small proportion of concentrates in the diet and significant green, juicy, and coarse feeds, the feeding of which leads to darkening of muscle and yellowing of adipose tissue.

The technological properties of beef related to storage and processing (yield during cooking) of beef products were investigated. According to the data (Table 4), the colour of muscle tissue can be used as an indicator of its degraded technological properties, since a probable (p>0.99) strong inverse correlation (r=-0.737) with its boiling is established.

Table 4. *Correlation between the colour of muscle tissue and the technological and sensory properties of beef*

Indicator	r
Boiling down of beef	-0.737**
Broth tasting	-0.047
Boiled beef tasting	-0.487

Note: **P>0.99
Source: compiled by the authors

Cooking beef greatly affects the sensory quality during consumption. This is considered only in the beef classification system (Meat Standards Australia, 2015). The consequence of the deterioration in the boiling down rate of meat was a lower yield during cooking and often to "dry (without juiciness)" beef. This led to high losses of cooked meat and meat products during water runoff, which also affected the yield and quality of processed meat. The loss of fluid from cooked meat is important for the meat industry because of its impact on the economy. As water is lost from the muscles during cooking, the proteins become less flexible and more rigid. With such a loss of water from beef during heat treatment, the product from it is coarser (Rahman *et al.,* 2020). Although with longer heating, the sarcoplasmic protein collagen becomes gelatinised and is able to retain water. The deterioration of the technological properties of muscle tissue with an improvement in the assessment of its colour can also be explained by the fact that collagen fibrils contract during heating. This leads to a loss of fluid in the meat, and to a decrease in its tenderness. Water is lost during the preparation of meat products due to denaturation of muscle proteins at different temperatures, which causes transverse and longitudinal shrinkage (Warner, 2023). The loss of moisture in meat

during its boiling also increased with an increase in its acidity (pH). The sensory quality of beef is becoming increasingly important to consumers.

To obtain data on the description of the nutritional quality of meat, it is determined by sensations during beef consumption and preferences for individual sensory responses during its consumption for taste, tenderness, juiciness, aroma, freshness, and leanness. The results of the correlations between the assessment of muscle tissue colour and the average values of sensory properties (aroma, juiciness, tenderness, chewiness) of cooked beef and beef broth (colour, taste, thickness). It is indicated that with an increase in the colour class of muscles, there was a tendency to worsen the values of tasting meat and broth, since the correlation coefficients between them were weak and inverse, respectively (r=-0.487 and -0.047). The main reason for the feedback between better beef colour development and its sensory properties is the lack of correlation (r=0.094) between the appearance of muscle tissue and its fat content. Beef tasting scores are not affected by its colour, also due to the fact that juiciness, which affects the quality of consumption and the amount of juice during chewing, also closely correlates with the fat content of beef (Listrat *et al.,* 2020), the amount of which, according to the researchers of the current study, does not increase due to colour changes. Beef, which is characterised by a low muscle fat content, is darker in colour, firmer, and drier.

Thus, the qualitative characteristics of beef are key. Studies by A. Hosseini (2022) have shown that the main problems with the quality of meat from cattle are associated with the non-compliance of consumer preferences with their consumer characteristics. The quality of beef is evaluated by the degree of marbling, colour of meat and fat, sensory characteristics – tenderness, aroma, juiciness, taste, smell, and appearance (Sakowski *et al.,* 2022). The main factor determining the quality of beef is a fat deposit in the middle of muscles or marbling. In the future, it is necessary to investigate the effect of intramuscular fat (marbling) on the quality characteristics of beef.

The variability of beef quality is very significant between animals, so according to A. Clinquart *et al.* (2023), it is not easy for consumers to evaluate it, except visually, only by the colour of muscle tissue and its fat content. Conventional beef quality assessment, which involves chemical and biological experiments, is tedious, time-consuming, destructive, and sometimes environmentally harmful. The consumer pays special attention to the sensory properties of beef, which are almost difficult to assess during the purchase. Predicting the sensory characteristics of meat was the main task. This was achieved based on the collected data after slaughter of animals and pre-determined relationships between them. In this paper, the approach to beef quality is applied in terms of providing an answer to the question of what its quality means for consumers, how they form expectations from it during purchase, and how it correlates with the quality that they perceive during consumption. Based on this, the relationship between the colour of meat and its physical (colour of meat and fat, marbling), sensory (sensations during consumption and preferences for individual reactions – taste, tenderness), technological (related to storage and processing, output during cooking), chemical (pH, water retention capacity, moisture and dry matter content, protein, total fat content, and ash weight) characteristics was studied.

According to the data obtained, the authors came to the conclusion that the colour of beef does not characterise its good sensory and culinary properties. With an increase in the colour class of muscles in the carcass, there is a deterioration in the boiling of meat, there is a tendency to reduce the fat content in the muscles, and some increase in the marbling of beef, and the deterioration of its tasting properties (taste, aroma, tenderness) and broth from it. In the

market, the cost of beef depends on the colour of muscle tissue, which the consumer uses to assess the freshness and healthiness (acceptability) of meat, since its colour affects the preferences and probability of its purchase. Colour measurement is more important for the visual perception of beef than the actual quality parameters. Therefore, it is vital to maximise the benefits of beef production by understanding the factors that affect the colour of meat and its deviation from bright red colour. Life-long factors that affect muscle colour include (Sakowski *et al.,* 2022) sex and age of animals, time spent on fattening them, seasonality, stress before slaughter, nutritional status, slaughter process, and meat maturation time.

In turn, consumers are interested in the nutritional value and sensory characteristics of beef and the prevention of their diseases (Randhawa *et al.,* 2021) from eating meat, which has become a pressing issue in recent years. For people's perception of beef quality information, about its sensory assessment used to describe the nutritional quality of meat becomes more complex as consumers' purchasing decisions become more sensitive to internal and external challenges, including food quality and safety, and environmental sustainability (Liu *et al.,* 2022). There are many problems regarding the assessment of Ukrainian black-and-white dairy cattle by the colour of muscle tissue, including the deterioration of many qualitative indicators of beef. 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. In this regard, Ukraine raises the question of solving the problem of producing beef that is attractive to buyers, which would combine the quality of meat with the prevention of their diseases.

In the future, it is necessary to conduct research on more animals of different breeds regarding the relationship between the colour of muscle tissue and the qualitative characteristics of beef, including meat, the colour of which, according to M. Hanson (2023), is most consistent with consumer preferences.

Conclusions

The EUROP classification system of beef carcasses in Europe by conformation, external fat content and its thickness has little to do with food quality for the consumer, does not reflect the composition of the carcass and the level of marbling (main quality characteristics).

Although the colour of muscle tissue does not characterise the good sensory and culinary properties of bulls of the Ukrainian black-and-white dairy breed, but it should be included in the quality characteristics of carcasses, since it is the first to indicate its freshness and affects the preferences of consumers and the probability of its purchase. The colour of muscle tissue inversely (r=-0.737) significantly (p>0.99) correlated with its boiling, which indicated a deterioration in its technological properties, showed a tendency to increase the water binding capacity (r=0.326), penetration (r=0.295), marbling (r=0.258), acidity (pH) (r=0.231), the cross-sectional area (r=0.341), the highest class of carcasses in the colour of muscle tissue it tended to have a relatively positive association with the overall tasting score of cooked meat (r=-0.487) and broth from it (r=-0.047). There was no correlation between the colour of muscle tissue and its chemical composition (moisture, dry matter, protein, and fat content) (r=-0.005 to 0.094). The tendency to correlation (r=-0.230) between the colour of muscle tissue and the subcutaneous fat thickness led to faster cooling of carcasses and caused an increase in beef stiffness, drying out, and a darker colour of muscle tissue

In the future, it is advisable to conduct similar studies on other breeds of cattle common in Ukraine and develop technologies for the production of beef that is attractive to buyers in colour, which would combine its qualitative

sensory characteristics. In the future, it is necessary to investigate the effect of intramuscular fat (marbling) on the quality characteristics of beef. Special attention should be paid to establishing the optimal thickness of subcutaneous adipose tissue, which ensures an adequate meat yield with a significant protein content and low fat concentration and a high amount of edible meat for consumers. Future research should focus on reducing water loss during beef storage, as this will reduce the amount of waste and improve its visual and sensory quality. Such data will provide consumers with additional information that will help them make an objective, useful choice when purchasing beef. This will become a theoretical basis for introducing indicators of the colour of muscle tissue, marbling of meat, the development of subcutaneous fat and its thickness into the carcass classification system in Ukraine.

Acknowledgements

None.

Conflict of Interest

None.

References

[1] Antoniuk, T. (2020). *Technology of animal slaughter products*. Retrieved from https://nubip.edu.ua/sites/default/files/u249/tehnologiya_produktiv_zaboyu_tvarin.pdf.

[2] ARRIVE guidelines. (2010). Retrieved from https://arriveguidelines.org/.

[3] Clinquart, A., Ellies-Oury, M.P., Hocquette, J.F., Guillier, L., Santé-Lhoutellier, V., & Prache, S. (2022). On-farm and processing factors affecting bovine carcass and meat quality. *Animal*, 16(1), article number 100426. doi: 10.1016/j.animal.2021.100426.

[4] Commission Regulation (EC). No. 1249/2008 "On 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". (2008, December). Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/9716803a-8887-4956-9877-629031ec7723/language-en 23.11.2018.

[5] Diler, A., Yanar, M., Özdemir, V.F., Aydin, R., Kaynar, Ö., Palangi, V., Lackner. M., & Koçyigit, R. (2022). Effects of slaughter age of holstein friesian bulls on meat quality: Chemical composition, textural characteristics, sensory attributes and fatty acid profile. *Foods*, 12(1), article number 158. doi: 10.3390/foods12010158.

[6] DSTU 4673:2006. (2011). *Cattle for slaughter. Technical conditions*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page?id_doc=91492.

[7] 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.

[8] DSTU ISO 1443:2005. (2007). *Meat and meat products. General specifications. Quality management systems*. Retrieved from https://zakon.isu.net.ua/sites/default/files/normdocs/dstu_iso_1443_2005.pdf.

[9] DSTU ISO 2917:2001. (2003). *Meat and meat products measurement of pH (control method)*. Retrieved from https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=89528.

[10] 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.

[11] 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.

[12] Hanson, M. (2023). *Crossbreeding improves most dairy beef*. Retrieved from https://www.dairyherd.com/news/dairy-production/crossbreeding-improves-most-dairy-beef-issues.

[13] Hosseini, A. (2022). *Relationship between trained sensory and objective measured meat quality attributes in crossbred Canadian beef cattle after 3-and 29-days post-mortem aging*. Retrieved from http://surl.li/rgwkg.

[14] Ijaz, M., Li, X., Zhang, D., Hussain, Z., Ren, C., Bai, Y., & Zheng, X. (2020). Association between meat color of DFD beef and other quality attributes. *Meat Science*, 161, article number 107954. doi: 10.1016/j.meatsci.2019.107954.

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

[16] King, D.A., Hunt, M.C., Barbut, S., Claus, J.R., Cornforth, D.P., Joseph, P., Kim, Y.H., Lindahl, G., Mancini, R.A., Nair, M.N., Merok, K.J., Milkowski, A., Mohan, A., Pohlman, F., Ramanathan, R., Raines, C.R., Seyfert, M., Sørheim, O., Suman, S.P., & Weber, M. (2023). American meat science association guidelines for meat color measurement. *Meat and Muscle Biology*, 6(4), 1-81. doi: 10.22175/mmb.12473.

[17] 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 adipose tissue. *Potravinarstvo Slovak Journal of Food Sciences*, 17, 997-1008. doi: 10.5219/1917.

[18] Listrat, A., Gagaoua, M., Normand, J., Andueza, D.J., Gruffat, D., Mairesse, G., Chesneau, G., Mourot, B.-P., Gobert, C., & Picard, B. (2020). Are there consistent relationships between major connective tissue components, intramuscular fat content, and muscle fiber types in cattle muscle? *Animal*, 14(6), 1204-1212. doi: 10.1017/s1751731119003422.

[19] Liu, J., Ellies-Oury, M.P., Stoyanchev, T., & Hocquette, J.F. (2022). Consumer perception of beef quality and how to control, improve and predict it? Focus on eating quality. *Foods*, 11(12), article number 1732. doi: 10.3390/foods11121732.

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

[21] Ministry for Food, Agriculture, Forestry, and Fisheries (MFAFF). Processing standard for meat products act, Grading, fabrication and cutting of beef carcass. (2007). Retrieved from https://ouci.dntb.gov.ua/en/works/lRjkBJal/.

[22] Moloney, A.P., O'Riordan, E.G., Monahan, F.J., & Richardson, R.I. (2022). The colour and sensory characteristics of longissimus muscle from beef cattle that grazed grass or consumed concentrates prior to slaughter. *Journal of the Science of Food and Agriculture*, 102(1), 113-120. doi: 10.1002/jsfa.11337.

[23] National Research Council of the National Academies. (2011). *Guide for the care and use of laboratory animals (8th ed.)*. Washington: National Academies Press.

[24] Order of the Ministry of Agrarian Policy and Food of Ukraine No. 652. "On Approval of the Procedure for the Use of Animals in Agriculture". (2012, October). Retrieved from https://zakon.rada.gov.ua/laws/show/z1898-12#Text.

[25] Osadcha, Yu.V. (2021). *Mathematical methods in biology. The textbook for university student of the specialty 204 – "Animal products manufacturing and processing technology"*. Kyiv: TSP "Komprynt".

[26] Rahman, M.F., Iqbal, A., Hashem, M.A., & Adedeji, A.A. (2020). Quality assessment of beef using computer vision technology. *Food Science of Animal Resources*, 40(6), article number 896. doi:10.5851/kosfa.2020.e57.

[27] Ramanathan, R., Denzer, M., Kiyimba, F., Harr, K., Suman, S.P., Hunt, M., Pffeifer, M., Mafi, G.G., & Kim, Y.H.B. (2023). Role of postmortem bioenergetics in beef colour chemistry. *Italian Journal of Animal Science*, 22(1), 711-727. doi: 10.1080/1828051X.2023.2240357.

[28] Randhawa, I.A.S., McGowan, M.R., Porto-Neto, L.R., Hayes, B.J., & Lyons, R.E. (2021). Comparison of genetic merit for weight and meat traits between the polled and horned cattle in multiple beef breeds. *Animals*, 11(3), article number 870. doi: 10.3390/ani11030870.

[29] Raza, S.H.A., Khan, R., Abdelnour, S.A., Abd El-Hack, M.E., Khafaga, A.F., Taha, A., Ohran, H., Mei, C., Schreurs, N.M., & Zan, L. (2019). Advances of molecular markers and their application for body variables and carcass traits in qinchuan cattle. *Genes*, 10(9), article number 717. doi: 10.3390/genes10090717.

[30] Rules pre-slaughter veterinary inspection of animals and veterinary sanitary examination of meat and meat products. (2002). Retrieved from https://ips.ligazakon.net/document/view/reg6812?an=11&ed=2002_06_07.

[31] 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.

[32] Santiago, B., Baldassini, W., Neto, O.M., Chardulo, L.A., Torres, R., Pereira, G., Curi, 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.

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

[34] Ugnivenko, A., Kruk, O., Nosevych, D., Antoniuk, T., Kryzhova, Y., Gruntovskyi, M., Prokopenko, N., Yemtcev, V., Kharsika, I., & Nesterenko, N. (2023). The expressiveness of meat forms of cattle depending on the content of adipose tissue under the skin and between the muscles. *Potravinarstvo Slovak Journal of Food Sciences*, 17, 358-370. doi: 10.5219/1869.

[35] United States standards for grades of feeder cattle. (2000). Retrieved from https://www.ams.usda.gov/sites/default/files/media/LiveFeederCattleGradeStandards.pdf.

[36] Warner, R.D. (2023). The eating quality of meat: IV – Water holding capacity and juiciness. In *Lawrie's meat science* (pp. 457-508). New Delhi: Woodhead Publishing. doi: 10.1016/B978-0-323-85408-5.00008-X.

Взаємозв'язок між хімічним складом, фізико-технологічними та сенсорними властивостями яловичини і кольором м'язової тканини

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

Анотація. У Японії, США, Кореї, Австралії колір м'язової тканини застосовують під час оцінювання якості туш яловичини, в той час як в країнах ЄС та Україні цю ознаку не враховують. Актуальність роботи полягала в обґрунтуванні необхідності врахування кольору м'язової тканини для оцінки споживчих властивостей яловичини. Метою дослідження було оцінити хімічний склад, сенсорні і фізико-технологічні властивості яловичини відповідно до забарвлення м'язової тканини. У дослідженні використовували туші 21-місячних бугайців (n=13) української чорно-рябої молочної худоби, забій яких провели після 24-годинного голодування за вільного доступу до води, в забійному цеху (с. Калинівка) Броварського району Київської області. Колір м'язової тканини у туші оцінили згідно з методикою японської асоціації класифікації яловичини. У фарші із *m. longissimus dorsi* дослідили загальний вміст жиру, вміст вологи та протеїну. Вивчили також кислотність (pH) яловичини, пенетрацію та вміст зв'язаної вологи. Споживчі властивості яловичини визначали шляхом проведення дегустації вареного м'яса (за ароматом, соковитістю, ніжністю, легкістю жування) і бульйону із нього (за кольором, смаком, міцністю). Було встановлено, що більш темний колір м'язової тканини мав вірогідну (P>0,99) зворотню кореляцію (r=-0,737) із уварюванням яловичини. Він проявляв тенденцію щодо прямої кореляції з площею «м'язового вічка» (r=0,341), водозв'язуючою здатністю (r=0,326), пенетрацією (r=0,295), кольором жирової тканини (r=0,267), мармуровістю (r=0,258), pH (r=0,231) і зворотньої – з вмістом мінеральних речовин (r=-0,309) і загальною оцінкою дегустації вареного м'яса (r=-0,487). Між забарвленням м'язів і вмістом у них вологи, сухої речовини, білку та жиру кореляція була відсутньою (r=від – 0,005 до 0,094). Практичне значення роботи полягає в можливості використання отриманих знань для сортування яловичих туш відповідно до призначення, а споживачам нададуть додаткову інформацію для об'єктивного вибору м'яса за урахування зв'язку між забарвленням м'язів та сенсорними і фізико-технологічними властивостями яловичини

Ключові слова: м'ясна продуктивність; мармуровість м'язів; фізико-технологічні і сенсорні властивості яловичини; хімічний склад м'яса; велика рогата худоба