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Beef quality and sensory traits in relation to subcutaneous fat color in dairy bulls

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ABSTRACT

The study examines the impact of subcutaneous adipose tissue color on beef quality traits in 18–24-month-old Ukrainian Black-and-White dairy bulls. Using a 7-point scale adapted from Japanese beef grading standards, carcasses were divided into two groups based on fat color: moderately white and moderately yellow. Results showed that yellower fat was generally associated with heavier animals and carcasses, darker beef color, and increased connective tissue content. A tendency was observed for improved carcass muscle structure, such as larger muscle eye area and higher-grade muscle tissue, among carcasses with more yellowish fat. However, this was also associated with lower subcutaneous fat thickness, a slightly reduced water-holding capacity, and minor decreases in meat moisture and broth flavor characteristics. Notably, the fat color did not significantly influence the broth's transparency or the tenderness and chewability of boiled meat. These findings suggest that adipose tissue color can reflect certain technological and sensory traits of beef, offering potential utility in carcass grading systems.

Keywords: meat, productivity, carcass, color, tissue, morphological composition, sensory evaluation

INTRODUCTION

The characteristics and effects of fat vary depending on the location of fat deposition in cattle. Visible adipose tissue (thickness, coverage, and color) on carcasses is a significant (36%) factor for consumers in selecting quality beef **[1]**, and predicting the price of cattle carcasses **[2]**. The magnitude of the premiums and discounts to the cost of carcasses based on the color of the fat tissue depends on the subjectivity of the evaluators and varies between slaughterhouses **[3]**. Predicting the quality of beef is less important than meat color. In China, the color of the fat tissue is evaluated according to the beef classification system of the Ministry of Agriculture (China standards for beef quality grades, 2000) **[4]**. In Japan, it is classified according to the association's requirements (JMGA, 2000) **[5]**. The color of adipose tissue is one of the main characteristics by which the quality of beef steaks is assessed in points. In different places of its cut, the color saturation of the adipose tissue is not the same **[6]**. Preference is given to carcasses with white fat and light beef in Mediterranean markets **[7]**. The most important external factor influencing the color of subcutaneous adipose tissue in cattle is feeding and the duration of consumption of each feed. In animals raised on pasture feed, the color of adipose tissue is yellower than in animals fed on concentrates **[8]**. This is due to the presence of carotenoids in fresh green grass and succulent feed, and does not depend on the quality of the carcasses, their maturation time, or the age of the animals at slaughter **[9]**. The metabolism of β-carotene and vitamin A in bulls is lower than in heifers **[10]**. Different breeds of animals require different lengths of time on a grain-based diet for the yellow color of the fat to decrease. Under the skin, it decreases mainly after 70 days of introducing concentrated feeds into the diet **[11]**. Some animals have yellow-colored fat tissue even after prolonged feeding on grain.

Determining the influence of the color of subcutaneous adipose tissue on the quantitative and qualitative characteristics of beef from dairy cattle is a relevant issue in Ukraine, as a significant proportion of beef is produced from this source. Therefore, the study aimed to evaluate slaughter indicators, morphological composition, and qualitative characteristics of carcasses and sensory attributes in 18-24-month-old bulls of the Ukrainian Black and Spotted Dairy Breed (UBSDB), depending on the color of subcutaneous adipose tissue.

Scientific Hypothesis

We hypothesized that the colour of adipose tissue under the skin in bulls of the Ukrainian Black-and-White dairy breed is not a reliable indicator for predicting the morphological composition, quality characteristics of carcasses and sensory properties of cooked meat and broth cattle. the color of the beef became significantly (P>0.05) darker by 10.2%.

Objectives

To determine whether there is a relationship between the color of subcutaneous adipose tissue in bulls aged 1.5 to 2 years and their slaughter performance, morphological composition and quality characteristics of carcasses, and sensory characteristics of beef

MATERIAL AND METHODS

Samples

Samples description: The study was conducted at the Zhuravushka farm in the Brovary district of the Kyiv region on 34 carcasses of 18-24-month-old bulls of the Ukrainian black-and-white dairy breed. The slaughter of the animals was carried out following the methodological approaches and requirements that comply with DSTU ISO/IEC 17025:2005 (2006) **[12]**. All manipulations with the bulls were carried out following the provisions of the "Procedure for conducting experiments on animals by scientific institutions (Law of Ukraine No. 249, 2012) **[13]** and the Convention of the European Commission for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (1986) **[14]**. Cattle for fattening were placed on sites that considered age and live weight. They had free access to the feeders from which they consumed roughage, juicy, green, concentrated feed, and mineral supplements according to the developed feeding rations. For the period from birth to 18-24 months of age, the structure of the rations was as follows: green feed 28.3%; silage - 9.6; hay - 8.6; haylage - 4.7; concentrates - 18.5%. Their pre-slaughter live weight was determined by weighing the bulls after fasting for 24 hours with free access to water.

The animals were slaughtered in the workshop of the village of Kalynivka. Within one hour after the slaughter of the bulls and their skinning, the carcasses were weighed on scales. Their conformation was visually assessed for classes E, U, R, O, P according to the Commission system. Regulation (EC) No. 1249/2008 (2008) **[15]**, which ensured compliance with European Union standards. For statistical data analysis, we converted their values into numbers on a scale from 1 (corresponding to P) to 5 (corresponding to E).

Samples collection: On a cross-section of m. longissimus back between the 12th and 13th ribs, where the half-carcass is divided into the front and back parts, the length and depth of the "muscle eye" were measured with a ruler.

Samples preparation: Fresh carcasses were sawn in half and weighed. Half carcasses were cooled and stored at 2°C for up to 24 hours. Then they were cut between the 12th and 13th ribs into quarters. Its area was calculated using formula 1 following the order of the Ministry of Agriculture of Ukraine No. 290 dated August 6, 2004. **[16]**:

$$S = a \times b \times 0.8; \qquad (1)$$

Where:

S is the area of the "muscle eye", cm^2;

a is the length of the "muscle eye", cm;

b – depth of the "muscle eye", cm; 0.8 is the coefficient.

The thickness of the fat on the carcass was assessed between the 12th and 13th rib with a ruler. The marbling of the meat was determined using a 12-point scale according to the JMGA (2000) method **[5]**. After de-veining, the muscle tissue was classified into the highest, first, and second grades according to the sausage classification **[17]**.

Number of samples analysed: 34 left half-carcasses were used for analysis in the conducted study, and 300 g of meat samples were selected from *m. longissimus back.*

Chemicals

No chemicals were used for the study.

Animals, Plants and Biological Materials

Carcasses of 18-24-month-old bulls of the Ukrainian black-and-white dairy breed from the Zhuravushka farm in the Brovary district of the Kyiv region.

Muscle tissue, subcutaneous fat, tendons and ligaments, bones, *m. longissimus back*.

Instruments

Static scales 4BDU-15X-P (Axis, Ukraine). Weighing unit ≥0.5 kg, weighing range from 10 to 1500 kg. Weighing of bulls monthly and before slaughter.

Gas chromatograph (Kupol_55, "Shimadzu Corporation", Japan).

Drying cabinet (SNOL, CHEMLABORREACTIV LLC, Ukraine).

Distiller for steam distillation of water (VELP Scientifica UDK 129, Italy).

Laboratory ionometer I-160M. Determination of pH of beef.

Automatic penetrometer PMDP. Determination of beef penetration.

Press. Determination of the amount of bound moisture.

Planimeter. Determination of the total area of a wet spot.

Ruler. Measuring the thickness of adipose tissue on a carcass.

Laboratory methods

In the laboratory of the Department of Meat, Fish and Seafood Technology of the National University of Life and Environmental Sciences of Ukraine (NULES of Ukraine), the total fat content in beef was determined according to DSTU ISO 1443:2005 **[18]**, the total ash mass - according to DSTU ISO 936:2008 **[19]**, the moisture content - according to DSTU ISO 1442:2005 **[20]**, and the pH - according to DSTU ISO 2917-2001 **[21]**.

The water-holding capacity of meat was investigated by the ratio of bound water content to the mass of meat in percent. The amount of bound moisture was determined by the "press method" by the content of water released from the meat under light pressing and absorbed into the filter paper, forming a wet spot. The spot area's size depends on the meat's ability to retain water. The better the moisture-holding capacity, the smaller the spot. The total area of the spot formed under the pressed meat and the released moisture absorbed by the filter paper was determined using a planimeter. The area of the wet spot was determined by the difference between the total area of the spot and the area occupied by the meat **[22]**.

The bound water content (%) in meat was found using formula (2):

$$X = \frac{(\mathrm{A} - 8.4 \times B)}{M} \times 100 \qquad (2)$$

Where:

X - content of bound moisture to the mass of meat, %;

A - moisture content in the sample, mg;

B - area of the wet spot, cm^2;

M - mass of meat, mg.

Eight tasters evaluated the sensory characteristics of boiled beef (aroma, juiciness, tenderness, ease of chewing) and broth from it (color, taste, strength) in the "Meat Quality" laboratory of the Department of Dairy and Beef Production Technology of the NULES of Ukraine according to the requirements given in the work **[22]**.

Description of the Experiment

Study flow: Before slaughter, animals were deprived of food for 24 hours with free access to water. Slaughter was carried out following European Regulation No. 1099/2009 of 24 September 2009 “On the protection of animals at the time of killing” **[23]**. After slaughter, the condition of the carcasses and the color and development of the subcutaneous adipose tissue were visually assessed.

After 24 hours of storage of carcasses at 2°C in a cold storage room, the fat layer's thickness, the muscles' marbling, and the length and depth of the "muscle eye" were determined. Then, the half-carcasses were deboned and skinned. From birth to 4 months of age, 34 bulls were kept in a group. Then they were fed with feed produced on the farm on a fattening site.

After slaughter, the degree of fat coverage of the carcasses was determined, the conformation (muscularity) of the carcasses, the thickness of the fat on the carcass, the color of the muscle and adipose tissue, the marbling of *m. longissimus dorsi*, the content of muscle tissue of the highest, first, and second grades, the chemical composition of beef, and the sensory properties of cooked meat and broth from it were assessed. The perception of tenderness was measured by the ease with which the teeth penetrated the meat initially and with which it disintegrated during chewing, as well as the amount of residue left behind. Satisfaction with the tenderness of the meat was based on the interaction between its texture and "mouthfeel" during biting and chewing.

When assessing the conformation of carcasses, their external appearance, symmetry, and development of muscle tissue were considered. Based on the amount of fat covering the outer side of the carcass and in the chest cavity, it was classified into 5 classes according to the system of Commission Regulation (EC) No 1249/2008 (2008) **[15]**. Following the JMGA (2000) **[5]** standard, the color of the subcutaneous fat tissue was assessed on a scale of 1 to 7 (Fig. 1). Standard color cards were used as a guide for this. The quality of the beef was classified according to the color of the fat (Table 1). The color range, according to the standard used for the assessment and visual perception, was compared with a reference color card under standardized lighting conditions to avoid the influence of its level or the angle of view from the outside. This allowed the obtaining of objective information on the color of the fatty tissue.

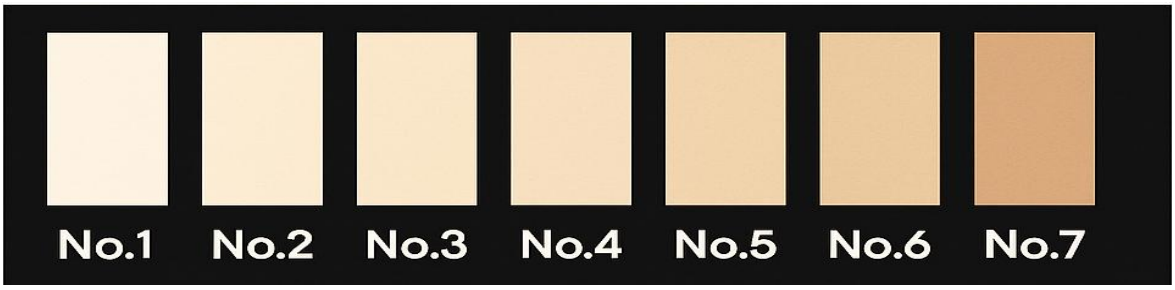

Figure 1 Adipose tissue color assessment scale according to the method (JMGA, 2000) **[5]**.

According to the color of the adipose tissue, 34 carcasses were divided into two groups: 1st – 3 and 4 points (n=10); 2nd – 5 and 6 points (n=24). This distribution allowed us to study in detail their morphological composition, technological properties of muscle tissue, and other qualitative characteristics of beef depending on the color of adipose tissue.

Table 1 Classification of beef quality depending on the color of the fat tissue under the skin (JMGA, 2000) **[5]**.

Quality grade	Fat color	BFS (beef fat standard)
5 Excellent	5 Excellent	No. 1, 2, 3, 4
4 Good	4 Good	No. 1, 2, 3, 4, 5
3 Medium	3 Medium	No. 1, 2, 3, 4, 5, 6
2 Below average	2 Below average	No. 1, 2, 3, 4, 5, 6, 7
1 Unsatisfactory	1 Unsatisfactory	Class "A"

Meat juiciness was defined as the perceived amount of juice and the level of lubrication during chewing in the mouth. Initial juiciness was determined, which is the impression of the liquid in the meat and is released during the first bite, which is associated with the water content in it. In addition, beef's persistent or overall juiciness, which was perceived during prolonged chewing, was investigated. It is associated with the fat content, which results from its stimulating effect on tasters' salivation. Muscle tissue samples were analyzed for sensory characteristics (tenderness, juiciness, taste, residue after chewing). The same experts assessed the nutritional quality of the meat. When determining these characteristics, the carcasses were divided into two groups depending on the color of the subcutaneous fat tissue (1st – 3.0 and 4.0 points; 2nd – 5.0 and 6.0 points).

Quality Assurance

Number of repeated analyses: the study was repeated 1 time, and the experimental data were processed using mathematical statistics.

Number of experimental repetitions: all studied characteristics were determined in the samples selected for the study only once.

Reference materials: Materials provided by the equipment manufacturer were used to check the equipment's performance.

Calibration: Each instrument was calibrated before each experiment, and calibration checks were performed regularly to maintain measurement accuracy.

Laboratory accreditation: The experiments were conducted at the "Ukrainian Laboratory of Quality and Safety of Agricultural and Industrial Complex Products", the management of which is carried out through the implementation of a management system built (since 2007) by the requirements of DSTU EN ISO/IEC 17025:2019 (EN ISO/IEC 17025:2017, IDT; ISO/IEC 17025:2017, IDT) and confirmed by the Accreditation Certificate of the National Accreditation Agency of Ukraine.

Data Access

Data supporting the findings of this study are not publicly available.

Statistical Analysis

We analyzed using statistics the mean value, the standard deviation of the group of characteristics: slaughter (live weight after starvation, slaughter weight, slaughter yield), morphological composition of carcasses (mass of muscle, including the highest, first, and second grades, adipose tissue, tendons and ligaments, bones), qualitative (conformation (fleshiness) of carcasses, development of fat cover on them and its thickness, marbling, color of muscle tissue, area of "muscle eye"), physical and technical indicators of beef (water-binding capacity, boiling, penetration), it's chemical composition (acidity (pH), moisture content, dry matter, protein, total fat content, total ash mass), sensory properties of boiled meat (juiciness, taste, aroma, tenderness, residue after chewing) and broth (taste and aroma, strength, transparency) with it. The experimental data was analysed using the Data Analysis in Microsoft Excel. Each experiment was performed with a minimum of three to five repetitions. The acquired results were subjected to standard processing methods and are presented as average values and standard errors of the mean (± SEM). Statistical results were assessed using the Student's t-test, with differences considered significant at $p < 0.05$.

Its purposeful use was aimed at obtaining objective data and analyzing it to identify regular patterns and make decisions regarding beef production based on optimal carcass quality indicators, as well as providing recommendations for its further processing.

RESULTS AND DISCUSSION

In the conducted study, 29.4% of carcasses were classified by the color of subcutaneous fat as "moderately white", and 70.6% – as "moderately yellow". The tendency to prefer carcasses with "moderately yellow" subcutaneous fat color over "moderately white" by 41.2 points occurred because the animals' diets contained a higher amount of green and succulent feeds and a lower amount of concentrated feeds. In studies **[11]**, heifers fattened on grass were also characterized by a greater (52.67%) amount of " moderately yellow" shade of fat on carcasses.

With different shades of color of adipose tissue under the skin, there was no significant difference between the animals of the groups in the signs of slaughter and the morphological composition of the carcasses (Table 2). With a less bright color (3 and 4 points) of adipose tissue under the skin, compared to its assessment of 5 and 6 points, there was a tendency to reduce the slaughter weight (carcass) by 3.8%.

In addition to the color of the fat covering the carcass, various factors influence the slaughter yield (carcass) in a non-uniform manner. Thus, with better carcass fatness, its percentage improves **[24]**, with better meat marbling, it decreases **[25]**, and with an increase in the area of pastures per animal, it does not affect the weight of the carcass **[26]**.

When evaluating the color of adipose tissue in a larger number (5 - 6) of points, there is a tendency to reduce the amount (by 2.7%) of muscle tissue. The tendency to reduce the content of muscle tissue in carcasses is also manifested by the selection of sons with a smaller number of antigens of the B blood group system similar to the mother **[27]**. With a yellower color of subcutaneous fat, there is a tendency to increase the content of muscle tissue in the carcass of the highest (by 12.3%) and first grades (by 4.7%).

The absolute and relative content of muscle tissue of the second grade were not significantly lower by 6.9% and 2.9 points, respectively, for the severity of the color of the adipose tissue (5 and 6 points). The absolute adipose tissue content in the carcass for its color of 5 and 6 points under the skin increased by 40.0% compared to its assessment of 3 and 4 points. In studies **[28]** also it was found that an increase in the mass of fat in the carcass was associated with a 3.76% increase in the yellowness of the adipose tissue. The tendency to increase the adipose tissue content in the carcasses of 18-month-old sons was also manifested by the homogeneous selection of parents according to the index of similarity of the B blood group system antigens, compared with peers from heterogeneous mating **[29]**. With a yellowness of the color of adipose tissue, estimated at 5 and 6 points, there is a tendency to increase by 0.5 points the relative content of tendons and ligaments in the carcass and, probably ($P \leq 0.05$), by 41.7% of their absolute number.

Table 2 Signs of slaughter and morphological composition of bull carcasses with different colors of subcutaneous adipose tissue.

Characteristic	**Color of adipose tissue**

	3 - 4 points (n =10)	5 - 6 points (n =24)
Live weight after starvation, kg	403±10.4	422±10.5
Slaughter weight (carcasses), kg	185.9±5.97	193.0±5.14
Slaughter yield (carcasses), %	46.1±0.21	45.7±0.23
Muscle tissue mass, kg	132.8±3.45	136.4±3.51
Muscle tissue, %	71.4±1.03	70.7±0.59
including top grade, kg	28.4±1.70	31.9±1.42
including top grade, %	21.4±0.98	23.4±1.42
-//- first grade, kg	61.1±1.97	64.0±1.86
-//- first grade, %	46.0±0.69	46.9±0.55
-//- second grade, kg	43.3±1.81	40.5±1.83
-//- second grade, %	32.6±1.25	29.7±1.15
Adipose tissue, kg	6.5±1.37	9.1±0.92
Adipose tissue, %	3.5±0.33	4.7±0.40
Tendons and ligaments, kg	2.4±0.18	3.4±0.20*
Tendons and ligaments, %	1.3±0.16	1.8±0.07
Bones, kg	44.2±0.99	44.1±1.33
Bones, %	23.8±0.56	22.8±0.53

Note: M± m – mean (M), its error (±m), *P≤0.05.

With a yellower color of the adipose tissue under the skin, there is only a tendency to increase (by 6.1%) the carcass conformation assessment (Table 3). In cattle, the fleshiness of the carcass is a breed trait, depending on the relationship between the genotype and the characteristics of animal growth **[30]** and the thickness of the subcutaneous fat **[31]**. With an increase in the assessment of the yellowness of the adipose tissue on the carcass, a tendency to a slight (by 8.0%) decrease in the development of its cover and an increase in its thickness by 35.9% was noted. In the study **[28]**, on the contrary, it was found that an increase in the assessment of carcasses for fatness was associated with an increase in the yellowness of the adipose tissue by 2.60%.

Table 3 Qualitative characteristics of bull carcasses with different assessments of the color of subcutaneous adipose tissue.

Characteristic	Color of adipose tissue	
	3 - 4 points (n =10)	5 - 6 points (n=24)
Conformation (meatiness) of carcasses, scores	3.3±0.27	3.5±0.24
Development of fat cover on carcass, scores	2.7±0.23	2.5±0.14
Thickness of subcutaneous adipose tissue, cm	0.64±0.084	0.87±0.083
Marbling of *m. longissimus dorsi*, points	4.8±1.14	5.6±0.67
Muscle tissue color, points	4.9±0.11	5.4±0.15*
Area of the "muscle eye" *m. longissimus dorsi* , cm^2	72.0±6.1	86.8±4.25

Note: M± m – mean (M), its error (±m), *P≤0.05.

The tendency we obtained for the deterioration of the fat cover on the carcass with a “moderately yellow” color of the adipose tissue indicates that with a better score for its evaluation, the qualitative characteristics of beef will not improve since they are better characterized by the development of the fat cover on the carcass **[32]**. With a greater thickness of subcutaneous fat, there is a tendency for deterioration of the slaughter yield (of the carcass), the sensory properties of beef, and the proportion of valuable edible parts of muscle tissue **[33]**. The presence of significantly thicker fat can explain the deterioration of the morphological composition of carcasses with a higher (5 and 6 points) color class of the adipose tissue under the skin. With a greater thickness, the percentage of muscle tissue yield decreases, because during the processing of beef at meat processing plants, processors remove excess fat deposited under the skin **[25]**.

There was a tendency towards a 16.7% better marbling of *m. longissimus dorsi* when assessing the color of adipose tissue at 5 and 6 points against its values at 3 and 4 points. No significant differences were found **[34]** between breeds in terms of marbling indicators ($P < 0.05$). The higher content of marbling in beef is a favorable

factor in its influence (P≤0.01) on the amount of muscle tissue in the carcass **[35]**. However, positive and strong correlations have been established on the contrary **[36]** between the marbling of beef and the level of monounsaturated fatty acids (r = 0.77) and polyunsaturated (r = 0.79) in it. This means that as the level of unsaturation of adipose tissue increases, its color becomes yellower.

When assessing the color of adipose tissue at 5 and 6 points compared to its class of 3 - 4 points, there was a tendency towards a 20.6% better area of the "muscle eye" *of the m. longissimus dorsi*. With a higher score (5 - 6 points) of the color of the adipose tissue under the skin in beef, there is a tendency to reduce the values of water-binding capacity (by 1.2 points), reducing (by 5.4 points) and penetration (by 26.7%) (Table 4). The tendency for the needle of the PMDP device to penetrate the beef sample to a smaller depth in 180 seconds indicates some of its stiffness and hardness with a higher value of the color of the adipose tissue, which reduces the content of fat, which protects the carcass from moisture loss in the refrigeration chamber, which ensures the juiciness of the boiled beef, to a certain extent retains water in it and binds it during processing. Losses of meat during water drainage negatively affect the yield of carcasses and muscle tissue of the 2nd grade and the quality of the boiled product.

Table 4 Technological characteristics of beef with different colors of fat on the carcass, M±m.

Color of adipose tissue, points	Characteristic		
	water-binding capacity, %	reduction, %	penetration, mm
3 - 4 (n = 6)	59.2±4.10	40.6±1.88	21.8±1.91
5 - 6 (n = 9)	58.0±4.74	35.2±2.01	17.2±2.17

With a better assessment (5 and 6 points) of the color of adipose tissue, there is a tendency to increase the moisture content in beef by 3.6 points and decrease acidity by 5.3%, dry matter content by 3.7 points, protein by 1.9 points, total fat content by 0.7 points and total ash mass by 1.1 points (Table 5). In Hanwoo cattle, no significant differences in the physicochemical properties of beef between animals with normal and yellow adipose tissue were also found **[9]**. An increase (P≤0.05) in the content of proteins associated with energy metabolism in bulls with better body conditions **[37]** can explain the manifestation of only a tendency to a simultaneous increase in the content of protein and total fat when assessing the color of subcutaneous adipose tissue at 3–4 points, compared to its classification at 5–6 points.

Table 5 Chemical composition of beef with different colors of adipose tissue on the carcass.

Color of adipose tissue, points	Characteristic					
	acidity (pH)	moisture content, %	dry matter, %	protein, %	total fat content, %	total ash mass, %
3 - 4 (n = 6)	6.0±0.22	68.5±2.15	31.6±2.15	21.9±0.92	7.0±1.32	2.7±0.47
5 - 6 (n = 9)	5.7±0.08	72.1±1.45	27.9±1.45	20.0±0.86	6.3±0.78	1.6±0.28

Note: M± m – mean (M), its error (±m)

With the color of the fat at 5 and 6 points, the pH of beef normalizes (5.7), and with a lower (3 - 4 points) value, atypical acidity (pH = 6.0) is manifested. In muscle tissue, with a decrease in pH, hydrolysis occurs more intensively, and lactic acid is formed, which causes microbiological processes to remain stable. With a lower assessment of the color and thickness of the adipose tissue on the carcass, there was a tendency to increase the protein content by 1.9 points in *m. longissimus dorsi,* which, with better fattening in bulls, is associated with energy metabolism, which contributed to the formation of meat with a higher content of adipose tissue in it.

With a higher assessment (5-6 points) of the color of adipose tissue, compared to its class of 3-4 points, there is a tendency to decrease by 6.1% the juiciness of cooked meat (Table 6). There was no difference in taste, aroma, tenderness, or the remaining beef after chewing between the samples of boiled meat. longissimus dorsi. The aroma of meat is formed mainly by chemical reactions during heating, which convert its precursors (sugar, proteins, lipids) into volatile compounds. These reactions also form the complex flavor profile of the cooked meat. The flavor of the beef is influenced by the species, sex, age of the animal, feed, and processing, which shape its physicochemical, sensory characteristics, and volatile compound content **[38]**.

Table 6 Sensory properties of boiled beef for different classes of color of adipose tissue on the carcass.

Color of adipose tissue,	Sensory characteristics of cooked meat, scores

points	succulence	taste	aroma	tenderness	residue after chewing
3 - 4 (n=6)	3.5±0.16	3.1±0.23	3.2±0.12	3.2±0.27	3.2±0.29
5 - 6 (n=9)	3.3±0.16	3.1±0.08	3.2±0.11	3.2±0.22	3.2±0.18

Note: M± m – mean (M), its error (±m)

With an increase in the color of fat under the skin, there was no increase in the main component of the sensory evaluation of beef - tenderness due to a decrease in the amount of fat in the meat, which softens the fibers, minimizes their destruction, and the content of proteins in it. With an increase in the color of subcutaneous fat, the manifestation of a tendency to deterioration in the evaluation of beef by an important characteristic - juiciness, which affects its nutritional quality, can be explained by a decrease in the fat content in the meat, which lubricates between the muscle fibers and increases its perception. Tenderness has a positive effect on the quality of beef consumption. In the mouth, juiciness characterizes the amount of juice during chewing, which is closely correlated with water retention in the middle of the muscles. With a higher color assessment of subcutaneous fat, the values of such sensory properties of beef as taste, aroma, tenderness, and residue after chewing did not change, also due to a decrease in the level of fat content in beef, which is associated with its increased sensory quality. Thus, increasing the assessment of the color of the fat leads to a decrease not only in the content of total fat in the middle of the muscles, but also does not worsen the estimated values of the characteristics of cooked meat aroma, taste, tenderness, and residue after chewing.

The results of our research indicate that an increase in the yellowness of subcutaneous fat in bulls did not significantly affect the sensory characteristics of broth from boiled meat. With a "moderately yellow" color of fat tissue compared to "moderately white", there are tendencies towards a slight (4.2%) improvement only in the taste and aroma of broth from boiled meat and a deterioration in its strength (by 4.2%) (Table 7). The color of the fat tissue did not affect the transparency of the broth.

Table 7 Sensory characteristics of boiled beef broth with different colors of adipose tissue under the skin.

Color of adipose tissue, points	Characteristics of broth tasting, scores		
	taste and aroma	strength	transparency
3 - 4 (n=6)	2.4±0.09	2.5±0.28	2.5±0.30
5 - 6 (n=9)	2.5±0.13	2.4±0.09	2.5±0.10

Note: M± m – mean (M), its error (±m)

The tendency towards a decrease in broth strength with an increase in the assessment of the color of subcutaneous fat can be explained by a reduction in the total fat content in the muscles and a decrease in its diffusion from the endomysium and perimysium cells into the boiled water. Fewer proteins, extractives, and mineral salts also pass into the broth due to a decrease in dry matter, protein, and total ash mass in the meat (see Table 5).

Therefore, the data obtained in our study indicate that with a "moderately yellow" (5–6 points) color of the subcutaneous fat tissue in the bulls of the Ukrainian Black-and-White Dairy breed aged 18 to 24 months, there is a statistically significant ($P<0.05$) increase of 10.2% in the assessment of muscle tissue color and a trend toward a 35.9% increase in fat thickness on the carcass. A positive and significant ($P\leq0.01$) correlation between the color of fat and muscle tissue was proven in the work **[39]**. The better expression of the quality trait of carcass thickness of subcutaneous fat and its associated quantity are interpreted differently in the literature. The positive aspects include **[40]** that carcasses are sorted and evaluated in the meat industry by the cover of fat tissue. It protects the carcass from moisture loss, increasing beef's rigidity **[41]**. Fat tissue is rich in essential nutrients, important components of beef food products. The nutritional value of this tissue depends significantly on its anatomical location. External fat is richer in conjugated linoleic acid than other types **[42]**. In carcasses of animals with yellow adipose tissue, compared with normal ones, beef has a higher ($P\leq0.05$) content of monounsaturated fatty acids **[9]**. Higher levels of unsaturated fatty acids may benefit consumers' cardiovascular health **[43]**. The fatty acids composition of beef should be the subject of special attention by producers and consumers because of their role in shaping human health. Polyunsaturated fatty acids help protect people from autoimmune diseases and cancer. In contrast, myristic and palmitic saturated fatty acids increase the risk of cardiovascular disease through the content of serum cholesterol and low-density lipoproteins **[44]**.

The color of adipose tissue is also an important factor in determining the freshness of beef and the first feelings of consumers regarding their willingness to buy it **[45]**. In our studies, a significant ($P<0.05$) increase in

the assessment of muscle tissue color with yellowing of adipose tissue should be explained by the considerable content of carotene-rich feeds in the diet of the studied bulls, which positively affect both the manifestation of the more yellow color of adipose tissue **[46]** as well as the darkening of the muscle **[47]**. In addition to the type of feeding, the color of beef is also significantly affected by the breed and sex of the bull **[48]**, and the acidity (pH) of the meat **[49]**.

The yellower color of the fat cover on the carcasses in our experiments did not significantly affect the marbling of beef, on which its nutritional quality **[50]** and juiciness **[51]** depend most. That is, the severity of beef marbling does not depend on the color of the fat tissue. It correlates with the cattle feeding level, their age, and live weight before slaughter **[52]**, and affects the color of the fat tissue under the skin **[53]**.

The negative aspects include **[31]** that a significant cover of carcasses with adipose tissue reduces the slaughter yield (carcass), the area of the "muscle eye" and the sensory properties of beef. The presence of a significant amount of fat under the skin can explain the deterioration of the relative content of muscle tissue in the carcass with a yellower color of fat, because at meat processing plants during beef processing, processors remove its excess **[25]**, since it is considered **[54]** waste. For high productivity and meat quality in bulls, the thickness of adipose tissue under the skin should be 8.0 mm **[55]**, and the minimum should be 3 mm **[56]**.

Scientists are investigating various possibilities for using technical animal fats. Thus, a technology for producing high-quality biodiesel fuel that meets modern requirements for waste technical animal fats and can be used in engines without significant re-equipment has been substantiated **[57]**. The authors have developed a hardware and technological configuration of a mobile installation for its production and proposed its technological support.

In our study, the “moderate yellow” color of the adipose tissue under the skin also tends to increase the area of the “muscle eye” by 20.6 %. The content of intramuscular fat, tenderness, taste, and juiciness of the meat did not significantly depend on the color of the subcutaneous adipose tissue.

Scientists are exploring various methods to enhance the quality and safety of meat products. An innovative technology has been developed **[58]** for utilizing probiotic cultures to produce meat products with enhanced organoleptic properties and additional functional benefits, aligning with the trends of healthy eating and meeting consumer demand for natural and environmentally friendly products. It has been substantiated **[59]** that the use of a starter based on a combination of Staphylococcus carnosus, *L. plantarum*, *L. rhamnosus*, and *L. paracasei* for the production of meat products activates microbiological processes, which improves the structural and mechanical properties of the meat product, increases water-binding capacity and has a positive effect on the quality of the finished product, reduces the duration of the technological cycle by 3-4 days, and ensures the absence of pathogenic and conditionally pathogenic microorganisms, low (up to 0.003%) residual sodium nitrites. A mathematical algorithm was built **[60]**, which allowed us to determine both the regularities of changes in the main parameters of the process of preparing minced meat semi-finished products with vegetable additives (spelt flour and champignon mushrooms) and the trends in the development of technical and technological efficiency of the means of mechanization of the system of fine grinding of raw materials for sausage products. Improved **[61]** the technology of production of semi-smoked sausages using spicy-aromatic plant ingredients, which allowed the production of products with an extended shelf life with a positive effect on lipid hydrolysis and inhibition of oxidative changes.

Based on the results of physical and mathematical modeling using the second similarity theory of Federman-Buckingham and the "dimensional analysis" method, the recipe of components and their ingredients was structured **[62]** in the process of centrifugal mixing with the addition of a multifunctional additive based on whey protein, sodium alginate, and soy fiber. This mixture demonstrated high characteristics in fat-binding and water-holding capacity, digestibility, pH activity level, and other parameters. The developed recipe improved the product's amino acid balance and enhanced its functional-technological and quality indicators. The biological value of meat and its health-improving properties of beef and its health-improving properties for humans are improved **[63]** by organic nitrite based on chard powder with bacterial culture.

Thus, the evaluation of carcasses of Ukrainian black-and-white dairy bulls according to the color of the subcutaneous fat tissue did not positively affect the morphological composition and qualitative characteristics of the carcasses in which consumers are interested. In cattle, its color depends on age, sex, breed of animals, location in the body, and diet, which is the most important external factor. Most carcasses of animals fattened on grain were characterized by a "moderately white” color of the subcutaneous fat tissue. In contrast, cattle fattened on grass had a predominantly “moderately yellow” color of the subcutaneous fat tissue **[11]**. This was caused by carotenoids from green feed, which have an undesirable effect on the appearance of beef since the yellow pigment in its subcutaneous fat tissue is not perceived by the consumer. Buyers refute their previously formed conclusion about beef quality by the color of the subcutaneous fat tissue, already during its consumption, according to the taste, tenderness, and juiciness they perceive. Jersey cattle have a yellower subcutaneous fat

color than Norwegian Red and Holstein Friesian cattle **[64]**. Although animals of different breeds in China fed similar diets, they did not differ in most parameters of subcutaneous fat color **[65]**. There is 2% less yellow pigmentation of subcutaneous fat in the scapula than in the anterior region of the back **[66]**.

Thus, there are many problems in evaluating carcasses of 18-24-month-old bulls of the Ukrainian black-and-white dairy breed by the color of subcutaneous fat, including the deterioration of many qualitative characteristics of muscle tissue. Due to the lack of its positive effect on the morphological composition and qualitative attributes of carcasses, the content of chemical substances in beef, and its sensory properties, it is impossible to use its values to predict the main quantitative and qualitative characteristics of meat. The color of adipose tissue and muscle tissue only indicates its freshness.

In this regard, the question arises about further research, including the use of the data intelligence analysis algorithm of the classification-regression tree **[67]**, to find the optimal values of the color of the subcutaneous fat tissue and to solve the problem of correlating them with the quality traits of beef and carcasses of dairy, combined, and meat breeds of animals raised for slaughter in Ukraine. To increase the accuracy of visual assessment of the color of adipose tissue and the sensory quality of meat, research should also be conducted to establish factors for managing the breeding of animals of these breeds, to form the optimal color under the skin and compromise with the sensory characteristics and chemical composition of beef and the prevention of consumer diseases.

CONCLUSION

In purebred 18–24-month-old bullocks of the Ukrainian Black-and-White Dairy breed, 29.4% of carcasses exhibited "moderately white" subcutaneous fat color, while 70.6% had "moderately yellow" fat. Carcasses with a fat color score of 5–6 points had a significantly higher (by 41.7%) absolute content of tendons and ligaments compared to those scored 3–4 points. These results indicate a reliable correlation between increased fat yellowness and connective tissue accumulation.

A tendency was noted toward darker beef color (by 10.2%) with increased fat yellowness, though the change was not statistically significant. Similar tendencies were observed for decreased slaughter yield (by 0.4 points), reduced absolute and relative amounts of second-grade muscle tissue (by 6.9% and 2.9 points), and minor declines in meat acidity, dry matter, protein, fat, and ash content, as well as water-binding capacity, boiling, and penetration characteristics. There was also a tendency toward reduced juiciness of boiled meat and broth strength. At the same time, increased fat yellowness was associated with higher adipose tissue content in carcasses (by 40.0% and 1.4 points), greater muscle eye area (by 20.6%), and improved broth taste and aroma. However, the color of the subcutaneous fat did not affect the broth's taste, aroma, tenderness, chew residue, or transparency.

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