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Quality of bull beef of the Ukrainian black and white dairy breed in dependence on the development of subcutaneous adipose tissue

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ABSTRACT

Determining the compliance of the quantitative and qualitative characteristics of the domestic cattle breed beef by the EUROP carcass standards is of great importance during Ukraine's accession to the European Union. The beef quality of a 21-month-old bull of the Ukrainian black and white dairy breed dependent on the subcutaneous adipose tissue development was evaluated at "Zhuravushka" FG in Kyiv region. From birth to 4 months of age, they were kept in groups of 25 heads. Growth and fattening were carried out at a feeding platform. For slaughter, the cattle were formed by a method of analogous groups. Following the EUROP system, the coverage of the carcasses with the subcutaneous fat was visually evaluated in five classes. The colour of the muscular and adipose tissue was determined by a scale of 1 to 7. The marbling of the muscular tissue was evaluated on a scale of 1 to 12, and the thickness of the carcass fat was measured between the 12th and 13th ribs as per the JMGA method. For chemical analysis to be conducted, 300 g of m. longissimus dorsi were taken from each cattle. The minced meat from that place was analyzed for total fat content – according to DSTU ISO1443:2005, mass, total ash - according to DSTU ISO 936-2008, moisture – according to DSTU ISO 1442-2005, pH – according to DSTU ISO 2917-2001 with the use of the laboratory ionometer (I-160M), penetration with the use of the automatic penetrometer PM DH in the laboratory of the department of meat, fish and seafood technologies of the National University of bioresources and nature management of Ukraine (NUBNMU). The beef's moisture-retaining capacity, broth tasting, and cooked meat were carried out in the "Meat Quality" laboratory of the Department of Milk and Meat Production Technologies of the NUBNMU. As the amount of subcutaneous fat increases, the marbling class of the bull beef does not increase. The development of the subcutaneous adipose tissue has no impact on the colour, pH, boiling, and transverse cut force of the beef. Due to better subcutaneous adipose tissue development, the meat has a higher moisture-retaining capacity than beef with its smaller amount. The development of the adipose tissue on the carcasses of the 21-month-old bull beef of the Ukrainian black and white dairy breed by the EUROP standard does not permit the prediction of the qualitative characteristics of the beef.

Keywords: meat productivity, bulls, fat (subcutaneous fat), intramuscular adipose tissue, Ukrainian black and white dairy breed

INTRODUCTION

There are certain differences between the evaluation criteria for beef in different countries. The European Union classifies beef carcasses by the EUROP system **[1]**. Following this system, when evaluating the carcasses, the class of the fat- subcutaneous fat is one of the main features determining their value. DSTU 4673-2006 "Cattle for slaughter. Technical conditions", developed in Ukraine **[2]**, provides for the evaluation of cattle only by live weight and carcass weight and does not consider subcutaneous fat thickness on them. For consumers' decision-making about beef purchase, the most important factor is the amount of visible fat (36%), followed by the price (25%), then its color (19%) **[3]**. But when there is a lot of subcutaneous fat, the yield of the carcasses and the proportion of their edible parts decreases **[4]**. It is not used to improve the meat quality **[5]**. Therefore, to adapt the Ukrainian standards to the requirements of the European Union by the EUROP system and to determine the need for their introduction into production, an urgent issue is to determine the impact of the development of the subcutaneous adipose tissue on the quality (technological, chemical and tasting properties) of the beef of the widely-spread Ukrainian black and white dairy breed.

The adipose tissue development in cattle depends on the breed and productivity **[6]**, age, and growth rate **[7]**. The development of the subcutaneous adipose tissue impacts beef quality by protecting the muscles in a refrigerating chamber against drying out when the carcasses are cooled, which might increase their stiffness **[8]**. This is a problem for the meat obtained from cattle with less adipose tissue **[9]**. Deposition of a large amount of the subcutaneous fat increases the feed consumption by the cattle during their growth **[10]**.

The beef fat has a low nutritional value in the processing industry. For healthy eating, people are forced to partially replace fatty raw materials with dietary ones **[11]**. The biological value of the meat is improved **[12]** by a fermentation method, and its human consumption and healthful properties are improved by the addition of rosemary extract **[13]**, iodine compounds **[14]**, citrus honey **[15]**, and protein-wheat texture, which contains a balanced set of amino acids **[16]**.

The beef source in Ukraine for the meat industry is the cattle of meat, dairy, combined breeds, and breeds obtained from their crossing. A great genetic diversity of the cattle produces different quality meat **[17]**. Consumers are interested in its nutritional value, sensory characteristics, and taste **[18]**.

The problem of meat quality formation in cattle with the different development of subcutaneous fat has not been sufficiently covered. Thus, the beef obtained from Limousin bulls at the ages of 25 to 27 months with the classes of the subcutaneous fat (by the EUROP requirements) "2" and "3" does not differ in tenderness **[19]**. Since fat distribution by fat depots is also the accounting subject of waste generation, disclosing the formation features of the qualitative characteristics of cattle beef is necessary to produce its components effectively. The article is aimed at determining the relationship between the qualitative characteristics (pH, moisture-retaining capacity and penetration of the longest back muscle, sensory properties) of the beef and the development of the subcutaneous adipose tissue, which characterizes the quality of the bull carcasses of the Ukrainian black and white dairy breed.

Scientific Hypothesis

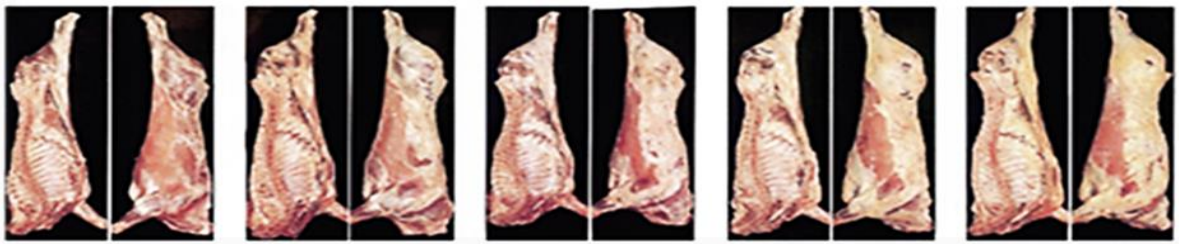
Previous studies have shown that the better development of the adipose tissue on the bull carcass negatively correlates to their growth rate and breeding value. Its impact on the formation of the qualitative characteristics of beef has not been confirmed. It is expected that the development of the subcutaneous adipose tissue of the cattle correlates to the fat content inside the muscles, which impacts certain sensory and technological properties of the beef. The deposition of various amounts of subcutaneous fat and its impact on the meat quality of the Ukrainian black and white dairy breed cattle can vary from the general trend of its formation in the cattle.

MATERIAL AND METHODOLOGY

13 Ukrainian black and white dairy breed bulls were studied at “Zhuravushka” FG in the Kyiv region. From birth to 4 months of age, they were kept in groups of 25 heads. Further, they were fed with the home-produced feed at the feeding platform by the rations adopted by the farm. The bulls were slaughtered at 21 months in the farm's slaughterhouse (Kalynivka village). The difference between the bulls in the group in terms of age and live weight was up to 5 % at the time of slaughter.

Samples

The coverage degree of the carcasses with the subcutaneous fat was classified into five classes (Figure 1): 1st (low) – the subcutaneous fat is almost absent; 2nd (slight) – a small amount of the subcutaneous fat, the muscles shows through almost the entire carcass; 3rd (average) – almost the entire carcass is covered with the fat, it is accumulated in the chest and shoulder parts; 5th (very high) – the entire carcass is covered with the fat without gaps, it is largely accumulated in the chest.



Low (1) Slight (2) Average (3) High (4) Very high (5)

Figure 1 Evaluation scale of subcutaneous fat **[1]**.

Under the JMGA method **[20]**, the colour of the muscular and fat tissue was evaluated with the use of a colour scale of 1 to 7, and the marbling of m. longissimus dorsi - between the 12th and 13th ribs. After slaughter, the meat piece (300 g) was selected from m. longissimus dorsi for chemical analysis to be conducted.

Chemicals

Solution of hydrochloric acid, 1.5 %, ("Khimlaborreaktyv" LLC, Ukraine)
Solution of sulfuric acid, 5 % ("Khimlaborreaktyv" LLC, Ukraine).
Chloroform ("Khimlaborreaktyv" LLC, Ukraine).

Animals, Plants, and Biological Materials

21-month-old bull of the Ukrainian black and white dairy breed, which belonged to "Zhuravushka" FG, Brovary district, Kyiv region.

Instruments

Stationary weighing scales 4BDU-15X-P ("Axis", Ukraine). Weight unit >0.5 kg, weighing range from 10 to 1500 kg. Weighing of the bulls before slaughter.
Gas chromatographer (Kupol_55, "Shimadzu Corporation", Japan).
Drying cabinet (SNOL, "Khimlaborreaktiv" LLC, Ukraine).
Distiller for steam distillation (Velp Scientifical UDK 129, "Khimlaborreaktiv" LLC, Italy).
Laboratory ionometer I-160M. Determination of beef pH.
Automatic penetrometer PMDP. Determination of beef penetration.

Laboratory Methods

The total fat content in m. longissimus dorsi was determined by DSTU ISO1443:2005 **[21]**, total ash mass – by DSTU ISO 936:2008 **[22]**, and moisture content – by DSTU ISO 1442:2005 **[23]**. The following physical and technological characteristics of the beef were also studied: pH – by DSTU ISO 2917-2001 **[24]**. The boiled beef (aroma, juiciness, tenderness, easy chewing) and broth (colour, taste, strength) were tasted by the requirements given in the article **[25]**. The bulls were formed into a group before slaughter by age, which did not exceed 5%.

For the development of the carcass fat to be determined, the bulls were slaughtered in the slaughterhouse (Kalynivka village). Up to that moment, their pre-slaughter live weight was determined by weighing before and after 24 hours of fasting with free access to water. After the cattle were slaughtered and skinned, their carcasses were weighed. After that, the development of the subcutaneous adipose tissue was evaluated by the EUROP classification **[1]**.

Description of the Experiment

Sample preparation: There are rules for antemortem inspection and veterinary-sanitary inspection of meat and meat products (2002) **[26]**. An hour after slaughter, 21-month-old cattle were examined for subcutaneous adipose tissue development. During the second calendar day, after boning and veining the slaughtered cattle, 13 samples of 300 g from m. longissimus dorsi were taken from each cattle.

Number of samples analyzed: From the conducted experiment for chemical analysis, 13 meat samples from m. longissimus dorsi of each 21-month-old cattle were used by one sample. In the minced meat from m. longissimus dorsi of the slaughtered bulls, the values of the qualitative characteristics were determined once at the age of 21 months**.**

Number of repeated analyses: The study was conducted 3 times.

Number of experiment replications: The number of repeats of each experiment to determine one value was also 3 times.

Design of the experiment: At the first stage, the bulls of the Ukrainian black and white dairy breed were kept in groups of 25 heads from birth to 4 months of age. After that, they were fed with the home-produced feed at the feeding platform. In the second stage, the bulls were slaughtered in the slaughterhouse (Kalynivka village) and the coverage degree of the carcasses with the subcutaneous fat was determined after slaughter. In the third

stage, the colour of the muscular and fat tissues, the marbling of m. longissimus dorsi, the chemical composition of the beef, and the technological and tasting properties were evaluated. At the last stage, the correlation relationship between the development of the subcutaneous fat and the sensory and technological properties was determined.

Statistical Analysis

The data was statistically processed using Microsoft Excel 2016 in combination with XLSTAT. The indicators were evaluated by the correlation coefficients, which were calculated by appropriate methods **[27]**.

RESULTS AND DISCUSSION

Indicators of the commercial classification of the carcasses of 21-month-old Ukrainian black-spotted dairy cows according to the development of fat were in the range from "weak" to "medium". The majority (61.1%) of them are assigned to class 2.5. Subcutaneous fat contributes to the trend towards the highest negative correlation with beef technological properties such as muscle eye area (r = -0.495) and acidity (r = -0.252) (Table 1). Therefore, the better development of fat under the skin, reducing the muscle cell area, simultaneously also leads to a decrease in the number of valuable edible parts in the carcass **[5]**. A decrease in the pH of muscle tissue occurs as a result of glycolysis, during which lactic acid is formed in the meat, and it is microbiologically more stable.

Table 1 Correlation between the development of fat on the carcass and technological properties of beef.

Feature	r
pH	-0.252
Moisture-retaining capacity	0.093
Penetration	0.137
Marbling	0.010
Fat thickness	-0.034
Loin eye area	-0.495

With the increase in the development of subcutaneous adipose tissue, the indicators of penetration (r = 0.137), which characterizes the structural and mechanical properties of beef, water-binding capacity (r = 0.093) and marbling of the medulla oblongata (r = 0.010) do not increase significantly. It is possible to change the water-binding capacity of meat and its structural and mechanical properties by finely grinding it **[28]**. The marbling class of beef increases with a simultaneous increase in fatty tissue under the skin **[29]**, although this was not found in some works **[19]**. Marbling is an important aspect of beef quality **[30]**. It is related to consumers' perception of meat and includes its physical (collagen tenderness and maturity) and chemical (moisture content, fatty acid composition, and antioxidant capacity) characteristics **[31]**. An increased level of marbling positively affects beef's tenderness, juiciness, aroma, and overall taste evaluation **[5]** when there are no off-flavours **[32]**. Between the evaluations of tenderness, juiciness, and taste of meat and fat content in the middle of the muscles, the curvilinear relationships are leveled at its value of 15-17% **[33]**.

With a better development of fatty fiber on the carcass, there is a tendency to worsen beef cooking and the general evaluation of the taste of cooked meat and its broth (Table 2).

Table 2 Correlation between the development of fat under the skin and organoleptic characteristics of beef.

Feature	r
Colour of muscular tissue	0.245
Colour of fat tissue	-0.543
Boiling	-0.144
Tasting broth	-0.328
Tasting Boiled meat	-0.288

The sensory properties of beef depend on marble fat located in the middle of the muscles **[34]**. When meat is fried or boiled, it melts, impregnating it. As a result, it becomes juicy and tender. The marbling of beef is influenced by the individual genetic characteristics of the cattle, their breed, sex, age at the time of slaughter, housing system, feeding level, and the temperature at which the meat is cooled and packed **[35]**. Intramuscular fat content in black wagyu cattle is about 30% **[36]**, and Ukrainian beef cattle is only 0.37-0.65% **[37]**. Among European breeds, the concentration of intramuscular fat is the highest in the beef of Aberdeen-Angus heifers

[38]. Meat marbling is better in steers **[39]** and in old cattle **[40]** when they are intensively fed concentrated feed with high energy content **[41]**, only after the "excess" fat accumulates in the middle of the belly, under the skin and between muscles **[42]**. The worst quality is the beef of uncastrated Bugai **[43]**. The morphology of marbling (coarse and small fat inclusions) especially affects beef's nutritional quality **[44]**. If the meat is coarsely marbled, it has a higher content of polyunsaturated fatty acids and aromatic compounds, and if it is fine-grained, the aroma and taste are better. However, consuming beef with high marbling does not benefit human health **[45]**.

Due to the increase in the development of fat under the skin, its color worsens and, accordingly, muscle tissue improves. Higher parameters of beef color and lower final pH for improving animal condition, which is affected by the content of subcutaneous fat **[46]**, were obtained **[47]** in crossbred (½ Angus x ½ Charolais) and purebred Charolais **[48]** animals. The color of beef is important for consumers to make decisions about its purchase **[49]**, as it is one of the first to be used to indicate the freshness and usefulness of meat **[50]**. The color of muscle tissue depends on myoglobin's concentration and chemical form **[35]**. Fresh meat contains deoxymyoglobin, oxymyoglobin, and metmyoglobin. Red pigmentation is given to it by deoxymyoglobin, which, in the presence of oxygen, is oxidized to oxymyoglobin and contributes to the manifestation of a bright pink-red color. When deoxymyoglobin and oxymyoglobin are oxidized to metmyoglobin, the meat turns brown. A decrease in the pH level, which leads to a better development of fat-irrigation, contributes to the formation of metmyoglobin. Metmyoglobin reductase reduces the concentration of an unwanted form of myoglobin in meat and stabilizes its color **[35]**. The color of beef is significantly influenced not only by its biochemistry, technological processing, and packaging but also by animal feeding **[51]**. Feeding animals on pastures with alfalfa, Bermuda grass, cowpeas, and pearl millet produces a richer meat color **[52]**. The color of meat products is improved **[53]** by using native lactic acid bacteria and gram-positive catalase-positive cocci.

The correlation between the visually assessed development of subcutaneous adipose tissue on the one hand and the chemical composition of beef on the other is moderate to low (Table 3). With better development of fatty tissue on the carcass, it practically did not change (r = 0.018) in m. longissimus dorsi moisture content, a large amount of which leads to rapid spoilage of beef **[54]**, and a tendency to increase protein content (r = 0.262) was observed.

Table 3 Correlation between the development of subcutaneous fat and the chemical composition of beef.

Feature	r
Moisture content	0.018
Solids content	-0.019
Protein	0.262
Fat	-0.262
Mineral substances	-0.089

Protein plays a key role in ATP production, energy exchange, oxidative stress, and redox processes in cells **[47]**. Under better conditions, the content of proteins related to energy metabolism increases in cattle. Under worse conditions, catabolic processes (glycolysis), oxidative stress, muscle structure, and contraction affect the meat's degree of marbling and color.

Using proteomics in combination with liquid chromatography and tandem mass spectrometry, 85 proteins were identified in Limousin cattle **[55]** that are correlated with tenderness, chewiness, hardness, and taste of meat. Predicted biomarkers were classified according to the interrelated biological directions of muscle contraction, energy metabolism of heat shock, oxidative stress, regulation of cellular processes, and binding.

According to our data, with better development of subcutaneous fat, the tendency to decrease (r = -0.262) the fat in meat is manifested in Bugai people. This does not confirm the probable connection between the investigated characteristics and does not allow for predicting the marbling of beef of 21-month-old Ukrainian dairy cows depending on the development of subcutaneous fat. The decrease in the content of fatty tissue in the muscles of cattle is the main reason for the negative effect of the better development of fat under the skin on the sensory properties of their meat. Beef, characterized by a low-fat muscle content, is darker in color, harder, and drier **[56]**. However, an increase in intramuscular fat with a higher class of subcutaneous adipose tissue development was observed in other **[19]** studies. The correlation coefficient between the development of subcutaneous fat, on the one hand, and the amount in m, on the other, is inverse and insignificant. longissimus dorsi of minerals that play an important role in human nutrition and health **[54]**.

Thus, based on the development of subcutaneous adipose tissue, assessed by the EUROP system in 21-month-old Ukrainian black-spotted dairy cattle, it is impossible to accurately predict the quality composition of

beef. Increasing the fat-watering on the carcass reduces its muscle content, does not give the beef more marbling, and worsens its tasting properties and the broth from it.

According to our data, improving the development of subcutaneous fat leads to increased water-binding capacity, which also characterizes juiciness, tenderness, and other technological properties of meat products. Due to this, the beef loses water during heat treatment, and the product becomes coarser. The quality of beef depends not only on the fat content in the middle of the muscles and their water-binding capacity but also on the interrelationship of the intramuscular connective tissue (general and insoluble collagen that surrounds the muscle fiber and their bundles and muscle as a whole) by types of muscle fibers and intramuscular fat **[57]**. The tenderness of meat depends on the amount of connective tissue, the diameter of muscle fibers, and the accumulation and distribution of fat in them. Bovine meat, characterized by a higher connective tissue content, is less tender and has greater losses during cooking **[35]**. Beef tenderness and subcutaneous fat thickness may be associated with the 526 T→ A mutation in the promoter region of exon 1 of the MyF – 5 gene **[58]**. A thin layer of fat on the carcasses and their rapid cooling are the reasons for increasing the stiffness of the beef, its drying, and the darker color of the muscle tissue **[59]**.

This shows that it is possible to preserve carcasses with sufficient subcutaneous adipose tissue. For 24-month-old bulls of British breeds and their crosses, a uniform adipose tissue thickness of 6.0 mm provides an adequate yield of edible beef in carcasses with high protein content and low fat concentration. It is a standard for consumers' quality of carcasses and meat products **[60]**. Today, they are interested in such properties of beef as nutritional value, sensory characteristics, and disease prevention **[61]**. In cattle, significantly developed fat under the skin is not desirable because it does not improve the quality characteristics of beef **[62]**, the number of scraps from carcasses during their stripping increases **[46]**, and the sexual precociousness of animals increases **[63]**.

Due to the accumulation of internal, subcutaneous, and intermuscular adipose tissue, which have a low value **[64]**, feed costs for their growth also increase **[65]**. Fat-watering is considered **[66]** to be a waste of beef production. Although there is already evidence **[67]** that external fat is richer in conjugated linoleic acid than other types. This could have important implications for human health and change how processors think about using fat trimmings from carcasses. It is necessary to reduce the deposition of subcutaneous adipose tissue for breeding animals obtained from inbreeding **[68]** and homozygous **[69]** and for a worse expression of meat forms **[46]**. Thus, there are many problems regarding the evaluation of carcasses of 21-month-old bulls of the Ukrainian black and mottled dairy breed for the best development of fat irrigation by the EUROP system, including high costs of feed for growth, live weight, deterioration of many quality characteristics of beef, disposal of raw trimmings or vice versa their use. Despite recent achievements in the world regarding regulating adipose tissue formation in cattle to improve the quality of beef from animals of breeds bred in Ukraine, this problem remains insufficiently resolved and calls for further research.

CONCLUSION

The assessment of cattle carcasses in Ukraine by DSTU 4673-2006, which provides for considering only live weight and carcass weight, differs significantly from EUROP requirements and does not take into account its conformation, thickness, and development of subcutaneous fat and the color and marbling of beef. The quality of carcasses of 21-month-old Ukrainian black-spotted dairy cows, classified by the development of subcutaneous adipose tissue by EUROP requirements, is not related to the quality of beef by sensory characteristics (evaluation in points of cooked meat and broth from it), and fat content in muscle tissue, its boiling. The better development of adipose tissue on the carcass is most negatively correlated with the area of the muscle eye, which indicates a decrease in the proportion of edible parts in the carcass. The development of adipose tissue under the skin practically does not correlate with the water-binding capacity, penetration, and marbling of beef. Additional research is needed on developing beef production technology with optimal development of inedible subcutaneous adipose tissue and appropriate levels of marbling to satisfy consumer preferences for meat quality and taste while preserving their health and supporting the economy of livestock farming.

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The authors have no conflicts of interest.

Ethical Statement:

According to Protocol No. 10 of 18.04.2020 at the meeting of the Ethics Commission of the Faculty of Livestock Raising and Water Bioresources, National University of Life and Environmental Sciences of Ukraine, Act No. 3 and 4 were signed during the experimental research, i.e. in the process of the slaughter of cattle "all the rules of the current legislation of Ukraine were observed, following DSTU 4673: 2006.

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