potravinárstvo®
OPEN ACCESS
Received: 10.9.2024
Revised: 30.10.2024
Accepted: 5.11.2024
Published: 6.11.2024

Slovak Journal of Food Sciences

Potravinarstvo Slovak Journal of Food Sciences
vol. 18, 2024, p. 977-992
https://doi.org/10.5219/2021
ISSN: 1337-0960 online
www.potravinarstvo.com

The effect of the carcass fat thickness on the qualitative technological and sensory attributes of beef

Olha Kruk, Anatolii Ugnivenko, Dmytro Nosevych, Oleksandr Natalich, Mykola Gruntkovskyi, Iryna Kharsika, Oleksandr Androshchuk, Inna Stetsiuk

ABSTRACT

The established correlations between subcutaneous fat thickness and the quality attributes of carcasses and beef are relevant for producers and the processing industry. The purpose of the study is to establish the characteristics of slaughter, chemical composition, sensory physical, and technological properties of beef made of young bulls belonging to the Ukrainian black-and-white dairy breed aged 18 to 24 months, depending on the thickness of the fat on the carcass. The colour of muscle and adipose tissue, the conformation of carcasses, the development of subcutaneous fat, marbling, chemical composition, and sensory attributes of beef and broth made of it were determined in the context of different fat thicknesses on the carcass. With an increase in the thickness of subcutaneous fat, the fleshiness (conformation) of carcasses increases by 55.2% (P>0.95), the cover of carcasses with fat increases by 43.5 (P>0.99), and muscle penetration improves by 45.8% (P>0.95). With the thickening of subcutaneous fat from 0.5 to 1.1 cm or more, there is a tendency of tendons and ligaments in carcasses to increase by 53.6%, with adipose tissue increasing by 25.6%, points for the juiciness of boiled beef increasing by 20.8%, its tenderness increasing by 12.5%, and the reduction in the m. longissimus dorsi 'loin eye' area increased by 7.3%, marbling increased by 19.0%, reduction of moisture content in meat increased by 27.8%, and its boiling properties increased by 7.9%. With an increase in the thickness of subcutaneous fat in beef, there was a tendency for the reduction of its acidity (pH), the amount of dry matter, the total content of fat and minerals, deterioration of taste, aroma, residue after chewing boiled meat, flavour, and aroma, concentration, and transparency of broth made of it. The practical significance of these studies is to obtain knowledge that allows the assessment of the quality characteristics of carcasses and beef by the thickness of subcutaneous fat for their further use by producers and processing industries.

Keywords: marbling, conformation of carcasses, muscle tissue, sensory attributes, subcutaneous fat

INTRODUCTION

In cattle, adipose tissue found under the skin is an important attribute of carcass quality, significantly affecting beef and the consumer's decision to purchase it, since visible fat is a significant (36%) factor when consumers choose **[1]**. Therefore, subcutaneous fat thickness was included in the Carcass Beef Grades and Standards (USDA, 2001) **[2]** Australia (MSA, 2015) **[3]**. They are used to classify, grade, and determine the quality of carcasses and describe their value for the meat industry **[4]**. Subcutaneous fat is considered **[5]** as both positive and negative beef quality criteria. It protects the carcass from losses during evaporation **[6]**, affecting the meat's tenderness **[7]**. Adipose tissue is a less wanted part of the carcass because it increases the animals' feed costs **[8]** and reduces the slaughter yield **[9]**.

Therefore, studies to determine the parameters of subcutaneous fat thickness in 18-24-month-old young bulls belonging to the Ukrainian black-and-white dairy breed, with which beef would have optimal slaughter,

physicotechnological, chemical, and tasting properties, are relevant. There would be a rationale for including them in Ukraine's regulatory documents for the classification of cattle carcasses.

In Ukraine, a significant share of beef is produced from animals of the Ukrainian black-and-white dairy breed (UBWDB). Specific aspects of quantitative and qualitative characteristics of meat made of them with different thicknesses of subcutaneous fat have not been studied. As a factor of differences in the taste of beef, it is a more important attribute of the quality of carcasses than conformation **[10]**. According to the MSA cattle carcass assessment system (2015) **[3]**, subcutaneous fat's minimum thickness is 3 mm. In each market, this value is to meet the consumer requirements. Increased thickness of fat under the skin (by 1 mm) reduces the cost of a kilogram of a carcass by 0.018 Australian dollars **[11]**, which is a key factor affecting the cost of beef. With increased subcutaneous fat thickness, carcass weight, fleshiness index, grade, and beef marbling deteriorate **[12]**. Subcutaneous fat does not affect meat's acidity (pH), colour, and boiling properties **[13]**. In young bulls with high productivity and meat quality, the subcutaneous fat thickness should be 8.0 mm **[14]**. The quality of beef depends on the fat content in the middle part of the muscles, which varies depending on the age and live weight of the animals and **[15]** their breed **[16]**.

Therefore, the purpose of the research was to evaluate the attributes of slaughter, chemical composition, sensory and physicotechnological properties of beef made the young bulls belonging to the Ukrainian black-and-white dairy breed in the period from 18 to 24 months of their age, depending on the thickness of subcutaneous adipose tissue, and to establish its optimal parameters, with which it would be possible to provide adequate meat and fat yields and significant technological and sensory attributes of edible beef for consumers.

Scientific Hypothesis

Previous research has shown that subcutaneous fat thickness is an important aspect of cattle carcasses. It affects the forecasting of the quality and quantity of beef, including its chemical composition, as consumers' cost and perception of meat during purchasing hinges on it. However, the relationship between the different thicknesses of subcutaneous fat and beef's physical, technological, chemical, and tasting characteristics in the Ukrainian black-and-white dairy breed animals may differ from the data obtained in previous studies on beef and beef and dairy cattle.

MATERIAL AND METHODOLOGY

Samples

The study in the Zhuravushka Farm, Brovary Raion, Kyiv Oblast involved 34 carcasses of 18-24-month-old young bulls of the Ukrainian black-and-white dairy (UBWD) breed. The animals were slaughtered in the slaughterhouse of the Zhuravushka Farm in the village of Kalynivka. The body weight of bulls was determined by weighing before slaughter after a 24-hour deprivation of food with free access to water. Fresh carcasses were sawn in half and weighed. The half-carcasses were cooled down and stored at +2°C for up to 24 hours. Next, they were cut into quarters between the 12th and 13th rib. On the cross-section of *m. longissimus dorsi* between the 12th and 13th rib, at the point where the half-carcass was divided into anterior and posterior parts, the length and depth of the 'loin eye' were measured according to the diagram shown in Figure 1, and the thickness of subcutaneous fat was measured with a ruler.

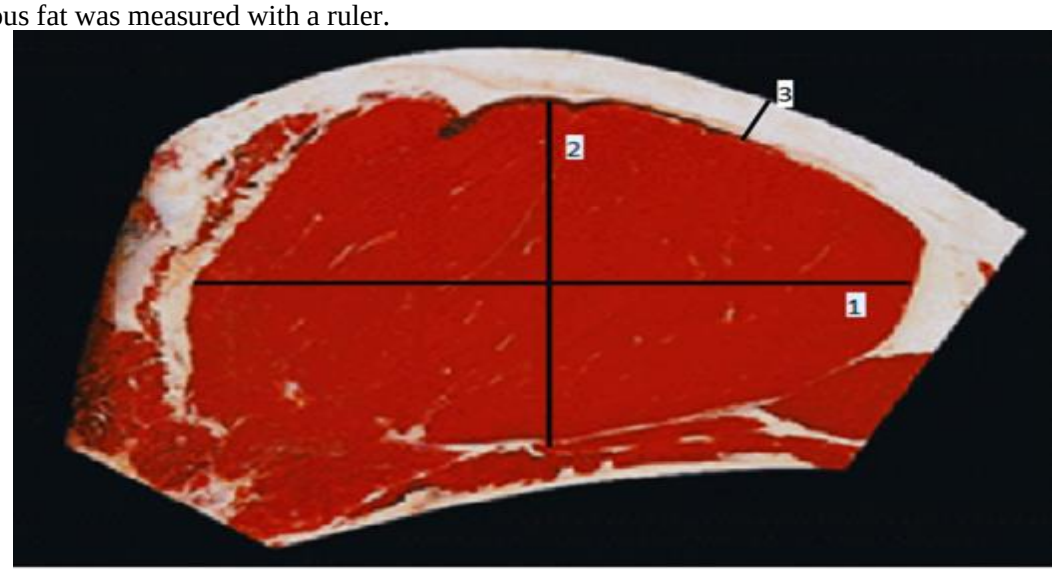

Figure 1 Length (1) and depth (2) of the 'loin eye' and measurement (3) of subcutaneous fat thickness.

The 'loin eye' area was calculated according to (formula 1) under the Order of the Ministry of Agrarian Policy and Food of Ukraine No. 290 of 6 August 2004 **[17]**:

$$S = a \times b \times 0{,}8 \quad (1)$$

Where: S is the area of the 'loin eye', cm^2; a is the length of the 'loin eye', cm;
b is the depth of the 'loin eye', cm; 0.8 is the coefficient.

On a scale of 1 to 7, according to the methods described in JMGA (2000) **[18]**, the color of the muscle (Figure 2) and fat (Figure 3) tissues was determined. According to the EUROP system (2008) **[19]**, the conformation of carcasses was visually classified into 5 classes (E, U, R, O, P) (Figure 4). For statistical analysis, we converted them into numbers on a scale of 1 (corresponds to P) to 5 (corresponds to E). The thickness of carcass fat was evaluated visually and broken down into five classes (from 1 = lean to 5 = very fat) (Figure 5). Marbling of meat was determined using a 12-point scale by the JMGA method (2000) **[18]** (Figure 6).

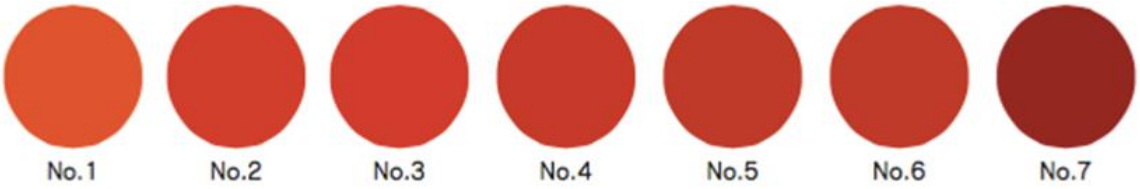

Figure 2 Muscle tissue color grading scale according to the method (JMGA, 2000) **[18]**.

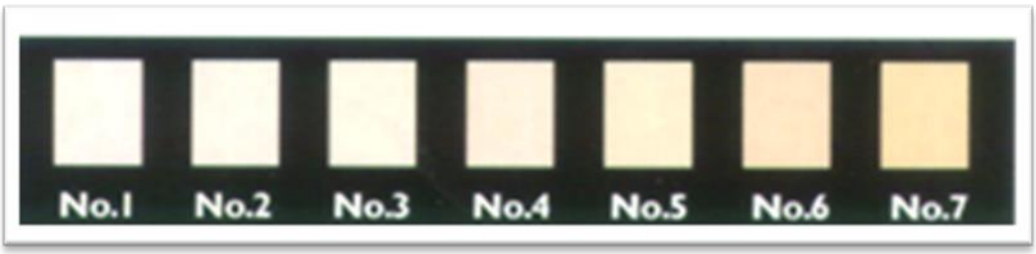

Figure 3 Adipose tissue color grading scale according to the method (JMGA, 2000) **[18]**.

Figure 4 Carcass conformation grading scale according to the system (EUROP, 2008) **[19]**.

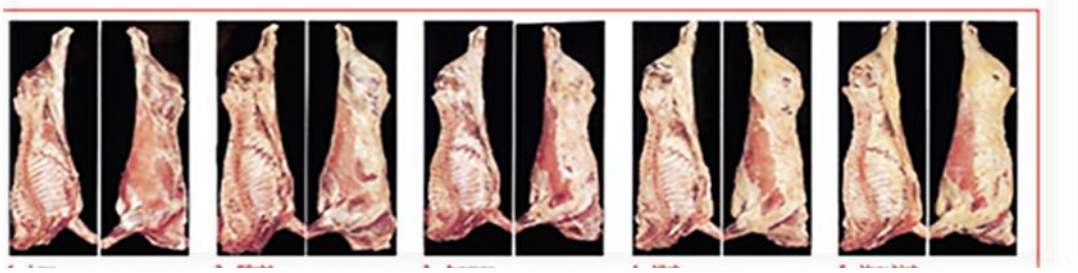

Figure 5 Carcass fat growth grading scale according to the EUROP system (2008) **[19]**.

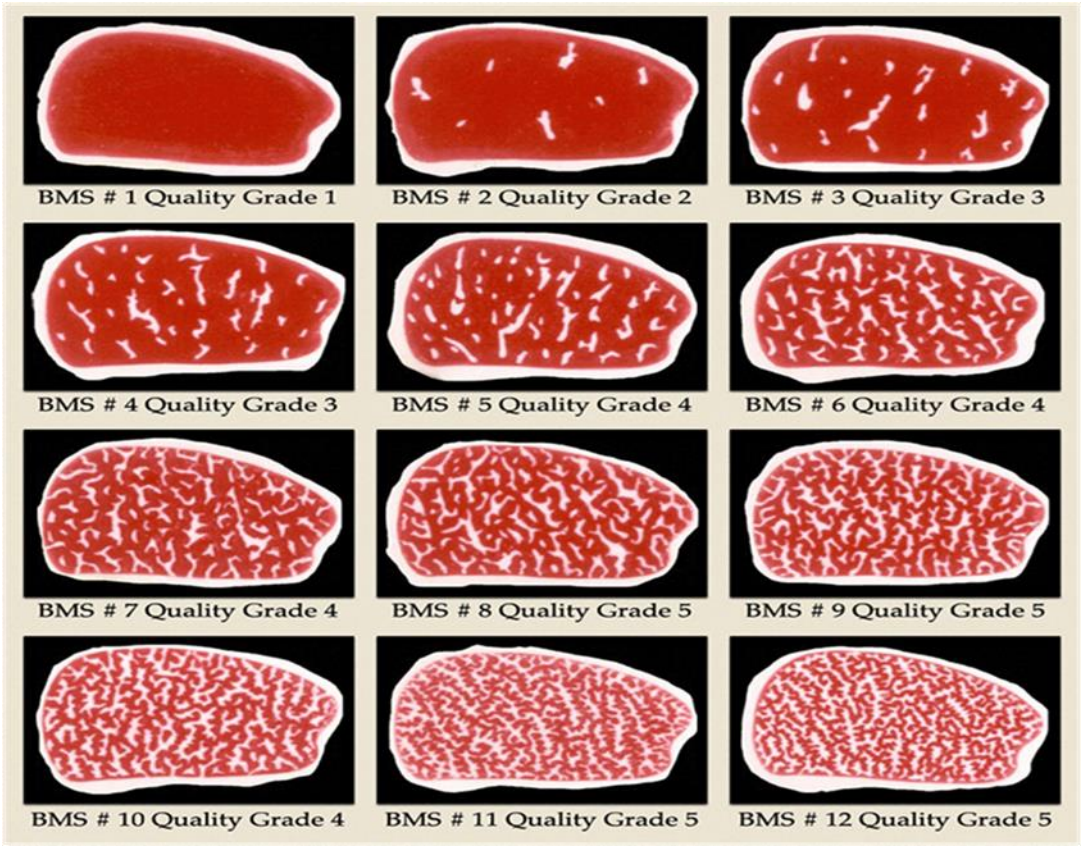

Figure 6 *M. longissimus dorsi* marbling grading scale according to the JMGA (2000) standard **[18]**.

Chemicals

Gel for ultrasound examination (Himlaborreactiv LLC, Ukraine).

Animals, Plants, and Biological Materials

Carcasses of young bulls belonging to the Ukrainian black-and-white dairy breed of Zhuravushka Farm, Brovary Raion, Kyiv Oblast.

Instruments

Static scales 4BDU-15X-P (Axis, Ukraine). Weight unit ≥0.5 kg, weighing range from 10 to 1,500 kg. Monthly weighing of young bulls and weighing before slaughter.

Gas chromatography (Kupol_55, Shimadzu Corporation, Japan).

Drying chamber (SNOL, Chemlaborreaktiv LLC, Ukraine).

Steam water distiller (Velp Scientific UDK 129, Italy).

Laboratory ionomer I-160M. Measurement of beef's pH.

Automatic penetrometer PMDP. Measurement of beef's penetration.

Ruler.

Laboratory Methods

The total fat content in beef was determined in the laboratory of the Department of Meat, Fish and Seafood Technologies of the National University of Life and Environmental Sciences of Ukraine (NULES of Ukraine) according to DSTU ISO 1443:2005 **[20]**; total ash content was determined according to DSTU ISO 936:2008 **[21]**; moisture content was determined according to DSTU ISO 1442:2005 **[22]**; and pH was determined according to DSTU ISO 2917-2001 **[23]**.

The moisture retention capacity of meat was studied using the content of bound water as a percentage of meat weight. The bound moisture content was determined by the 'press method' by the amount 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 retention capacity, the smaller the wet spot. Using a planimeter, the total area of the wet spot that forms under the compressed meat and the released moisture absorbed by the filter paper was defined. The area of the wet spot was defined by the difference between the total area of the spot and the area occupied by meat **[24]**.

The content of bound water (%) in meat was found using the formula (2) **[25]**:

$$B = \frac{(A - 8.4 \times b) \times 100}{M} \quad (2)$$

Where: B is the bound moisture content about the weight of meat, %;
A is the moisture content in the weighed average sample, mg;
b is the wet spot area, cm^2;
M is a weighted average meat sample, mg.

Eight tasters in the ' Meat Quality ' laboratory of the Department of Milk and Meat Production Technologies, NULES of Ukraine, evaluated the sensory attributes of boiled beef (aroma, juiciness, tenderness, ease of chewing) and broth made of it (color, taste, concentration) according to the requirements set out in the paper **[25]**.

Description of the Experiment

Sample preparation: Before slaughter, the animals were deprived of food for 24 hours with free access to water. The slaughtering was carried out by the European Regulation No. 1099/2009 of 24 September 2009 'On the Protection of Animals at the Time of Killing' **[26]**. After slaughtering young bulls, carcasses' conformation and subcutaneous adipose tissue development were visually examined. After 24-hour storage of carcasses at +2°C in the refrigerator, the thickness of subcutaneous fat, muscle marbling, length, and depth of the 'loin eye' were defined.

Number of samples analyzed: in the experiment, 34 left half-carcasses and *m. longissimus dorsi* samples were used for analysis.

Number of repeated analyses: all the studied attributes were determined in the samples selected for the study only once.

Number of experiment replications: Each study was carried out five times, and the number of samples was three, resulting in fifteen repeated analyses.

Design of the experiment: from birth to 4 months of age, 34 young bulls were kept in a group. Then, they had feed (produced on the farm) on the fattening site. After slaughtering, the degree of fat covering the carcasses was defined in young bulls, with the conformation (muscularity) of carcasses, the thickness of fat on the carcass, the colour of muscle and adipose tissue, and the marbling of *m. longissimus dorsi* defined. In determining these attributes, the carcasses were divided into three groups depending on the thickness of fat covering them (0.5-0.7 cm; 0.8-1.0 cm; 1.1 cm and more). In determining the chemical composition of beef and its technological and tasting properties, carcasses were divided into two groups 0.5-0.7 cm and 0.8-1.0 cm fat thickness. Experts conducted a tasting of boiled meat to study its sensory attributes. The degree of meat tenderness was defined by the ease with which teeth first penetrate the meat with which it breaks down during chewing, and the amount of residue left after it. Satisfaction with the tenderness of the meat was based on the interaction between its texture and the 'sensation in the mouth' during biting and chewing.

The juiciness of meat was defined as the perceived amount of juice and the level of lubrication when chewing. They determined the initial juiciness, which evaluates the liquid in the meat released during the first bite, associated with the water content. Besides, the persistent or general juiciness of beef during prolonged chewing was studied, and it was associated with the fat content, which stimulates saliva production in tasters. Muscle tissue samples were analysed according to sensory attributes (tenderness, juiciness, taste, residue after chewing). The same experts evaluated the nutritional quality of meat.

Statistical Analysis

Statistical analysis was used in the following aspects of the studies described above. Comparative analysis was performed: the quality of beef carcasses was compared between different groups of animals in the context of the thickness of fat under the skin.

Microsoft Exel 2016 was used to perform statistical analysis of the data obtained to determine the arithmetic mean (M), its error (±m), and the reliability criterion (td) between the groups.

The purposeful use of statistical analysis in this context was to collect objective data, analyze it to identify dependencies and patterns and support decision-making in beef production with maximum quality indicators and recommendations for further processing.

RESULTS AND DISCUSSION

Thicker fat on the carcass is the reason for the reduction in the slaughter yield, muscle tissue, in particular the first-grade muscle tissue, bone content, increase in adipose tissue, tendons and ligaments in the carcass, and the second-grade meat (Table 1). A decrease in the slaughter yield, the proportion of muscle tissue, and other attributes as specified in previous research papers associated with different thicknesses of fat on the carcass **[7]**, and its growth **[27]**, which mainly depends on related mating **[28]**, cattle breeds **[29]**, and fleshiness of animals **[30]**.

Table 1 Attributes of slaughter and morphological composition of young bull carcasses with different fat thicknesses on the carcass, M±m.

Attribute	Thickness of fat on the carcass, cm.		
	0.5 – 0.7 (n=19)	0.8 – 1.0 (n=9)	1.1 and more (n=6)
Body weight after the deprivation of food, kg	407±9.2	425±22.3	434±16.4
Slaughter output (carcass), %	45.9±0.15	45.6±0.11	45.5±0.91
Muscle tissue, %	71.1±0.80	70.6±0.74	70.8±1.21
including the top-grade meat, %	22.8±0.80	22.6±1.34	22.8±1.81
- //- first-grade meat, %	47.2±0.60	45.2±0.72	46.8±1.13
- //- second-grade meat, %	30.0±1.19	32.2±1.87	30.4±2.64
Adipose tissue, %	4.4±0.41	3.7±0.85	5.2±0.21
Tendons and ligaments, %	1.5±0.14	1.6±0.14	2.2±0.22
Bones, %	23.0±0.50	24.1±0.41	21.8±1.35

Table 2 shows the main qualitative attributes of carcasses, depending on the thickness of fat covering them. With an increase in subcutaneous fat from 0.5 – 0.7 to more than 1.1 cm, they improve by 43.5 (P>0.99), and the fleshiness (conformation) of carcasses increases by 55.2% (P>0.95) since animals have higher indicators with better growth of adipose tissue under the skin **[31]**.

Table 2 Qualitative attributes of young bull carcasses with different subcutaneous fat thickness, M±m.

Thickness of fat on the carcass, cm	Attributes					
	conformation of carcasses, points	growth of fat on the carcasses, points	'loin eye' area, cm^2	marbling of beef, points	muscle tissue color, points	adipose tissue color, points
From 0.5 to 0.7 (n=19)	2.9±0.97	2.3±0.11	83.7±4.79	5.0±0.85	5.1±0.13	4.6±0.14
From 0.8 to 1.0 (n=9)	3.7±0.25	2.6±0.26	83.0±9.73	7.1±0.74	5.4±0.18	4.9±0.12
1.1 and more (n=6)	4.5±0.37*	3.3±0.23**	78.0±4.49	4.2±1.34	5.3±0.46	5.0±0.49

Notes: *)P>0.95; **)P>0.99.

An increase in fat thickness from 1.1 cm and more is the reason for reducing the *m. longissimus dorsi* 'loin eye' area by 7.3%, directly correlating with the carcass weight and the amount of muscle tissue, including the top- and first-grade meat **[32]**. A decrease in the 'loin eye' area with the growth of adipose tissue under the skin confirms the data obtained in previous studies **[33]**. This confirms that with a larger subcutaneous fat thickness, the growth of *m. longissimus dorsi* decreases, meaning the number of valuable edible parts in the carcass also decreases. A decrease in the 'loin eye' area, the slaughter weight, and the amount of muscle tissue, including top- and first-grade meat with the growth of fat under the skin, can be explained by the fact that *m. longissimus dorsi* is located mainly in the thoracic and lumbar regions, which are the most valuable meat pieces, and their muscle tissue makes up a significant proportion of the carcass. However, there is data **[34]** that the 'loin eye' area increases with an increase in the fat thickness on the carcass from 3 to 25 mm and depends on the genotype of animals **[35]**. Due to the direct relationship between the 'loin eye' area and the output of valuable meat pieces in carcasses **[36]**, data on its value suggests **[37]** using it to forecast the amount of beef obtained and its belonging to a particular grade.

The beef marbling grade increases by 42.0%, with the thickness of adipose tissue on the carcass being in the 0.8 to 1.0 cm range. With its increase of more than 1.1 cm, the beef marbling decreases by 19.0%. The fact that the thickness of fat on the carcass does not directly correlate with the marbling of beef was also established in previous studies **[38]**. This means that it is impossible to obtain good sensory attributes of beef with thicker subcutaneous fat. Marbling is the main factor determining the sensory quality of meat **[39]**, it has a positive effect on its taste **[40]** and tenderness **[41]**.

With an increase in fat thickness on the carcass, the muscle tissue colour grade increases since its lower content is associated with a decrease in the discolouration of beef **[42]**. Deeper muscle tissue colour affects the consumer's choice **[43]**. Therefore, it is used to indicate meat freshness **[44]**. The muscle tissue colour depends on the chemical form of myoglobin **[45]**. Fresh beef contains deoxymyoglobin, which renders it red pigmentation. In the presence of oxygen, it is oxidised to oxymyoglobin. This results in a bright pink-red meat colour. When deoxymyoglobin is oxidised to methemoglobin, beef acquires a brownish shade. The beef colour improves with an increase in adipose tissue thickness on the carcass. Similar data was obtained in previous research, too **[34]**.

The results of the defined penetration strain show that with the fat thickness on the carcass ranging from 0.5 to 0.7 cm, the needle of the PMDP device penetrates the beef sample in 180 seconds (P>0.95) to a lower depth (by 45.8%), which speaks for its toughness, than with a larger (0.7-1.0 cm) fat thickness value (Table 3).

Table 3 Technological attributes of beef with a different fat thickness on the carcass, M±m.

Thickness of fat on the carcass, cm	Attributes		
	water binding capacity, %	boiling properties, %	penetration, mm
from 0.5 to 0.7 (n=11)	62.1±2.99	38.1±1.95	20.7±1.78
from 0.8 to 1.0 (n=4)	48.6±6.92	35.3±2.35	14.2±1.79*

Note: *)P>0.95.

This can be explained by the fact that the higher subcutaneous fat content protects the carcass kept in the refrigerator from drying out and losing its moisture, which ensures the juiciness of the finished product **[7]** associated with a reduction in the destruction and deformation of muscle fibers **[46]**. In young bulls, fat significantly affects the texture of meat **[47];** therefore, to prevent the contracting of muscle fibres, which makes the boiled beef tough, its thickness under the skin should be at least 5.00 mm. **[48]**. With a small amount of subcutaneous fat in the muscles, the temperature quickly decreases, and the fibers contract due to a decrease in the glycolysis process **[49]**. This is typical for more tough and dehydrated meat.

To a certain extent, subcutaneous adipose tissue retains water in the meat and binds it during processing. Therefore, with an increase in the thickness of subcutaneous fat, the water retention capacity reduces by 13.5 points. Retaining water in fresh meat is associated with its suitability for storage and better yield after cooking **[50]**. According to our data, a larger fat thickness on the carcass helps reduce the amount of moisture in boiled beef by 2.8 points. Other researchers have confirmed the established properties **[51]**.

Meat losses during water draining negatively affect the weight of carcasses and meat pieces and the yield and quality of processed products **[52]**. Due to beef's water loss during heating, the proteins become less elastic and tougher. The penetration strain increases because the product becomes tough **[53]**. The deterioration of the technological properties of muscle tissue with a smaller subcutaneous fat thickness can also be explained by the fact that collagen fibrils contract during heating. Denaturation of muscle proteins occurs at different temperatures.

Therefore, reducing the boiling time for beef means improving its culinary and technological properties. It is an important aspect that indicates the economic value of meat since its higher indicators increase waste during cooking. There is a suggestion to improve the water binding capacity and structural and mechanical properties of meat by grinding it fine **[54]**, by using a starter culture based on a combination of *Staphylococcus carnosus*, *L. plantarum*, *L. rhamnosus*, and *L. paracasei (SC$_2$)* **[55]**, centrifugal mixing of components of a multifunctional protein additive made from whey, sodium alginate, and soy fiber **[56]**. It is possible to improve the quality of meat and extend its term of preservation by treating carcasses with microorganisms of *Leuconostoc carnosum* and *Lactobacillus sakei* strains **[57]**.

The total fat content of beef reduces with an increase in the thickness of adipose tissue under the skin (Table 4).

Table 4 Chemical composition of beef with different thicknesses of fat on the carcass, M±m.

Thickness of fat on the carcass, cm	Attributes					
	acidity (pH)	moisture content, %	dry matter, %	protein, %	total fat content, %	total ash content, %
from 0.5 to 0.7 (n=11)	5.89±0.131	69.8±1.26	30.7±1.38	20.9±0.85	7.6±0.48	2.1±0.34
from 0.8 to 1.0 (n=4)	5.73±0.114	74.3±1.88	25.6±1.88	20.1±0.75	3.6±1.18	1.9±0.60

This contradicts data obtained during previous studies **[38]**. According to it, there is an apparent relationship between these attributes. Beef tends to increase in moisture content with an increase in subcutaneous fat thickness, which is explained by better protection of carcasses from crusting and losses.

In groups of carcasses with different adipose tissue thicknesses, the pH level was defined, which was compared with the classification scale (normal pH ≤5.8; atypical pH >5.8 but <6; typical DFD pH ≥6), used in **[58]**. In the range from 8 to 10 mm, the thickness of subcutaneous fat results in the normalisation of the PH (5.73) of beef, and with its smaller value, atypical acidity occurs (pH=5.89). Atypical beef has a higher level of methemoglobin **[46]**, which negatively affects meat penetration (see Table 3). With thicker subcutaneous fat and lower pH in muscle tissue, the glycolysis process occurs more intensively, with lactic acid developed. Due to this, it remains microbiologically stable.

With a smaller adipose tissue thickness on the carcass, the protein content in *m. longissimus dorsi* increased by 4.0%. With a lower degree of fatness in young bulls, the content of proteins associated with catabolic processes (glycolysis), muscle structure, and contraction increases (P≤0.05). With a higher degree of fatness, it is associated with energy metabolism **[59]**. In young bulls, with a larger thickness of adipose tissue, meat formed on the carcass with lower indicators of total ash content. Therefore, the evaluation of carcasses of young bulls belonging to the Ukrainian black-and-white dairy breed at the age of 18 to 24 months by subcutaneous fat thickness does not allow producers to forecast the chemical composition of beef depending on its size before slaughter.

The conducted tasting of boiled beef showed that with an increase in fat thickness on the carcass, there was a tendency to increase (by 12.5%) the main component of sensory evaluation of beef, that is, its tenderness (Table 5). It is affected by the amount and type of fat present in meat **[60]**, which softens the fibers and minimises their destruction **[42]**. Positive changes in experts' perception of beef tenderness are caused by the fat thickness on the carcass exceeding 6 mm. **[61]**.

Table 5 Sensory properties of boiled beef with different fat thicknesses on the carcass, M±m.

Thickness of fat on the carcass, cm	Sensory properties of cooked meat, points				
	juiciness	taste	aroma	tenderness	residue after chewing
0.5 to 0.7 (n=9)	2.4±0.10	2.6±0.13	3.1±0.15	2.4±0.07	3.3±0.16
from 0.8 to 1.0 (n=4)	2.9±0.30	2.4±0.41	2.7±0.28	2.7±0.50	2.9±0.31

With an increase in subcutaneous fat thickness, there is also a tendency to increase the rating of beef by 20.8% according to an important feature: juiciness, which affects its nutritional quality. Fat that lubricates muscles between fibres increases the degree of tenderness and juiciness of the meat. Juiciness has a positive effect on the quality of beef consumption. In the mouth, it is characterised by the amount of juice during chewing **[62]**, which closely correlates (r= 0.67) with the fat content in the middle of the muscle **[63]**. With a higher subcutaneous fat thickness, there is a tendency to reduce the values of such sensory attributes of beef as taste, aroma and residue after chewing. The taste of beef is affected by marbled fat, which contains more oleic acid and less stearic acid than subcutaneous fat. **[64]**.

Fat is also a source of aromatic compounds, which is important for meat quality. The aroma and taste of beef appear due to the reaction of non-volatile fatty acids during heat treatment and the type and concentration of volatile substances being released **[65]**. Thus, an increase in subcutaneous fat thickness leads to a decrease in the total fat content in the middle of the muscles and a deterioration in the estimated values of attributes of cooked meat aroma, taste, and residue after chewing.

After tasting boiled beef broth, the indicators were slightly higher graded, and the fat thickness on the carcass was smaller (from 0.5 to 0.7 cm) (Table 6).

Table 6 Sensory attributes of boiled beef broth with different fat thicknesses on the carcass, M±m.

Thickness of fat on the carcass, cm	Attributes of broth tasting, points		
	taste and aroma	concentration	transparency
0.5 to 0.7 (n=9)	3.1±0.13	3.1±0.23	3.0±0.25
from 0.8 to 1.0 (n=4)	2.9±0.14	2.8±0.33	2.4±0.24

With an increase in subcutaneous fat thickness, the broth concentration lowers since, with a decrease in the total fat content in the muscles, it diffuses from the endomysium and peremysium cells into boiled water to a lesser extent. Reduced dry matter, protein, and total ash content in meat (see Table 4) means less protein, extractive matter, and mineral salts enter the broth.

So, the results obtained show that with an increase in the thickness of subcutaneous fat in the young bulls of the Ukrainian black-and-white dairy breed aged 18 to 24 months, there is an apparent improvement in the conformation (fleshiness) of carcasses, the growth of adipose tissue and the penetration of meat, and a tendency to improving its tenderness and juiciness. The qualitative feature of carcasses – the thickness of subcutaneous fat – does not significantly affect the slaughter yield or the weight of muscle tissue, including the top- and first-grade meat, which correlate with the *m. longissimus dorsi* 'loin eye' area **[66]**. With an increase in subcutaneous fat, the chemical composition of muscle tissue tends to worsen. Besides, the larger thickness of adipose tissue under the skin does not affect the sensory attributes of boiled beef broth. With a larger subcutaneous fat thickness, muscle tissue's pH decreases due to glycolysis. For 18-24-month-old young bulls belonging to the Ukrainian black-and-white dairy breed, the optimal adipose tissue thickness on the carcass should range from 8 to 10 mm.

In this study, various statistical analysis methods were used to study the quality of beef carcasses, particularly the characteristics of the "muscle eye" zone. The main aspects of the analysis included the following:

Comparative analysis: The quality of beef carcasses from different groups of animals was compared. In particular, the "muscle eye" zone was evaluated according to parameters, including the average size and structure of muscle fibres. This approach made it possible to determine the difference between groups based on objective meat quality characteristics.

Correlation analysis: relationships between quality indicators of beef carcasses and parameters of the "muscle eye" zone were identified and analysed. In particular, the dependence of such characteristics as muscle mass, fat content, and moisture was investigated, which helped determine the relationships between physicochemical parameters and structural features of muscle tissue.

Analysis of changes over time: the dynamics of changes in the quality of beef carcasses and indicators of the "muscle eye" zone over time were studied. This study involved evaluating the changes that occur under the influence of various factors, such as adjusting the diet or increasing the level of physical activity of the animals. Such studies have helped to identify long-term trends and dependencies affecting meat quality.

Factor analysis: The study of the "muscle eye" zone determined the main factors significantly impacting the quality of the beef carcass. This analysis helped us better understand which parameters have the greatest influence on the structure and quality of meat and establish their importance to produce high-quality products.

Analysis of variance (ANOVA): was used to assess differences between groups of animals concerning their carcass quality and muscle eye characteristics. This method made it possible to establish which factors significantly impact beef meat quality accurately. 6. Regression analysis: was used to assess the influence of individual variables on beef carcass quality, for example, the dependence of meat quality on nutritional parameters, animal breed, or level of physical activity. Regression models helped to identify the main variables influencing product structure and quality.

Cluster analysis was used to group the studied carcasses based on similarities in the quality parameters of the muscle eye. This made it possible to single out groups of carcasses with similar quality characteristics and to identify optimal parameters for creating a high-quality product.

Principal component analysis (PCA): was used to reduce the dimensionality of the data and simplify the interpretation of the results, allowing the identification of the main factors affecting beef quality. This method made it easier to highlight the most important indicators determining carcasses' quality. The complex use of various statistical analysis methods made it possible to obtain objective and comprehensive data on the quality of beef carcasses, particularly the "muscle eye" zone.

The comparative, correlational, factorial, dispersion, and regression analyses conducted revealed significant regularities and interrelationships between carcass quality indicators and numerous factors, such as animal nutrition and physical activity. Thanks to this study, the key factors influencing the quality of beef meat were

identified, and the obtained results can serve as a basis for making decisions in the field of production optimisation to ensure high-quality standards.

Although the increased content of beef fat under the skin protects the muscles from dehydration in the refrigerator **[7]**, it has a low nutritional value, so it is considered **[67]** waste. To make human nutrition healthy, **[68]** options are developed to replace fatty raw materials with dietary ones. Health-improving properties of meat are boosted with rosemary extract **[69]**, iodine compounds **[70]**, textured wheat protein **[71]**, by grinding **[72]**, with sea salt and betanin dye made of beet juice **[73]**. Beef fat is used to develop **[74]** diesel fuel production technologies.

Beef producers and processors are focused on the quality of carcasses, determined by the thickness of adipose tissue the price in the market depends on. The thickness of subcutaneous fat, which determines the degree of fatness of cattle in Ukraine, does not positively affect the sensory and culinary attributes of beef required by consumers **[75]**. The tenderness, taste, and juiciness of meat depend **[76]** on the adipose tissue content in the middle of the muscles. Young bulls of the Ukrainian black-and-white dairy breed aged 18 to 24 months with a thickness of adipose tissue on the carcass ranging from 8 to 10 mm have a fat content in the middle of the muscles making up 3.6% only. Since the quality characteristics of carcasses compared with the quality of beef are more sensitive to changes in the management of ruminant breeding, it is possible to achieve their optimal combination under different feeding conditions **[41]** of cattle.

In this regard, in Ukraine, there is an issue raised of solving the problem of beef production, which should combine the quality of beef and carcass. In the future, researchers should focus on establishing the optimal thickness of subcutaneous fat in cattle of other breeds, as this will reduce the amount of waste from carcasses and improve their visual and sensory quality. It is necessary to research to determine the quantitative and qualitative attributes of beef and establish factors for managing the breeding of cattle of common Ukrainian breeds, to reach a compromise between the thickness of subcutaneous fat and technological and sensory attributes and chemical composition of meat.

Further scientific research is needed to study the relationship between the thickness of adipose tissue on the carcass and the quantitative and qualitative characteristics of beef and to establish factors for managing the breeding of cattle of common Ukrainian breeds to reach a compromise between the thickness of fat on the carcass and the technological and sensory characteristics of meat and its chemical composition.

CONCLUSION

With an increase in the thickness of subcutaneous fat, the fleshiness (conformation) of carcasses significantly improves by 55.2% (P>0.95), the growth of adipose tissue increases by 43.5% (P>0.99), the penetration of meat increases by 45.8% (P>0.95), the content of adipose tissue, tendons, ligaments, and bones increases, and the juiciness and tenderness of boiled meat graded increases.

With an increase in the thickness of fat on the carcass, there is a reduction in the slaughter yield (of a carcass), muscle tissue of the top- and first-grade meat, the *m. longissimus dorsi* 'loin eye' area, marbling, moisture retention capacity, boiling properties and acidity (pH) of beef, the amount of dry matter, the total content of fat, ash, and protein, the taste and aroma of boiled beef, the concentration and transparency of broth.

The optimal thickness of subcutaneous adipose tissue in young bulls of the Ukrainian black-and-white dairy breed aged 18 to 24 months should be 8 to 10 mm.

In the future, it is advisable to research the relationship between the thickness of adipose tissue on the carcass and the quantitative and qualitative characteristics of beef and establish factors for managing the breeding of cattle of common Ukrainian breeds to reach a compromise between the thickness of fat on the carcass and the technological and sensory characteristics of meat and its chemical composition.

REFERENCES

1. Rondoni, A., & Grasso, S. (2021). Consumers behavior towards carbon footprint labels on food: A review of the literature and discussion of industry implications. In Journal of Cleaner Production (Vol. 301, p. 127031). Elsevier BV. https://doi.org/10.1016/j.jclepro.2021.127031
2. Realini C. E., Kallas Z., Pérez-Juan M., Gómez I., Olleta J. L., Beriain M. J., Albertí P., Sañudo C. (2014). The relative importance of cues underlying Spanish consumers' beef choice and segmentation, and consumer liking of beef enriched with n-3 and CLA fatty acids. In Food Quality and Preference. (Vol. 33. pp. 74–85). Elsevier BV. https://doi.org/10.1016/j.foodqual.2013.11.007
3. USDA. (2001) United States Standards for Grades of Feeder Cattle.
4. Meat Standards Australia (MSA). 2015. Available at: https://www.mla.com.au/globalassets/mla-corporate/marketing-beef-and-lamb/documents/meat-standards-australia/msa-2015-16-annual-outcomes-report.pdf

5. Brito, G., Soares de Lima, J. M., Del Campo, M., Luzardo, S., Correa, D., & Montossi, F. (2024). The implementation of grading systems for beef carcass value differentiation: the Uruguayan experience. In Animal Frontiers. (Vol. 14, Issue 2, pp. 29–34). National Institutes of Health. https://doi.org/10.1093/af/vfae004
6. Hocquette, J. F., Gondret, F., Baéza, E., Médale, F., Jurie, C., & Pethick, D. W. (2010). Intramuscular fat content in meat-producing animals: development, genetic and nutritional control, and identification of putative markers. In Animal. (Vol 4, Issue 2, pp. 303–319). National Institutes of Health. https://doi.org/10.1017/S1751731109991091
7. da Silva Bernardo, A. P., Ribeiro, F. A., Calkins, C. R., & Pflanzer, S. B. (2020). Bone and subcutaneous fat influence on yield, physicochemical traits, and color stability of dry-aged loin from grass-fed nellore bulls. In Meat and Muscle Biology. (Vol. 4, Issue 1, pp. 1–8). Iowa State University Digital Press. https://doi.org/10.22175/mmb.11141.
8. Malheiros, J. M., Baldassini, W. A., Dias, V. A. D., Silva, J. A. I. V., Curi, R. A., & Chardulo, L. A. L. (2015). Chemical and sensory meat characteristics of Nellore cattle (Bos indicus) finished with different levels of backfat thickness in the longissimus thoracis muscle. In Boletim da Indústria Animal Nova Odessa. (Vol 72, Issue 4, pp. 341–348). Boletim de Indústria Animal. http://dx.doi.org/10.17523/bia.v72n4p3411
9. Ugnivenko, A., Nosevych, D., Antoniuk, T., Chumachenko, I., Ivaniuta, A., Slobodyanyuk, N., Kryzhova, Y., Rozbytska, T., Gruntovskyi, M., & Marchyshyna, Y. (2022). Manifestation of living and post-slaughter traits of productivity in inbred and outbred bull calves of Ukrainian meat cattle breed. In Potravinarstvo Slovak Journal of Food Sciences. (Vol 16, pp. 356–366). HACCP Consulting. https://doi.org/10.5219/1769
10. Ju, M. S., Jo, Y. H., Kim, Y. R., Ghassemi Nejad, J., Lee, J. G., & Lee, H. G. (2024). Supplementation of complex natural feed additive containing (C. militaris, probiotics and red ginseng by-product) on rumen-fermentation, growth performance and carcass characteristics in Korean native steers. In Frontiers in Veterinary Science. (Vol. 10, p. 1300518). National Institutes of Health https://doi.org/10.3389/fvets.2023.1300518
11. Riley, R. R., Savell, J. W., Murphey, C. E., Smith, G. C., Stiffler, D. M., & Cross, H. R. (1983). Effects of electrical stimulation, subcutaneous fat thickness and masculinity traits on palatability of beef from young bull carcasses. In Journal of Animal Science. (Vol. 56, Issue 3, pp. 584–591). Oxford Academic. https://doi.org/10.2527/jas1983.563584x
12. Polkinghorne, R., Philpott, J., Gee, A., Doljanin, A., & Innes, J. (2008). Development of a commercial system to apply the Meat Standards Australia grading model to optimise the return on eating quality in a beef supply chain. In Australian Journal of Experimental Agriculture. (Vol. 48, Issue 11, pp. 1451–1458). CSIRO PUBLISHING. https://doi.org/10.1071/EA05181
13. Palamarchuk, I., Zozulyak, O., Mushtruk, M., Petrychenko, I., Slobodyanyuk, N., Domin, O., Udodov, S., Semenova, O., Karpovych, I., & Blishch, R. (2022). The intensification of dehydration process of pectin-containing raw materials. In Potravinarstvo Slovak Journal of Food Sciences (Vol. 16, pp. 15–26). HACCP Consulting. https://doi.org/10.5219/1711
14. Song, Z., & Hwang, I. (2023). Objective meat quality from quality grade and backfat thickness of Hanwoo steers. In Food Science of Animal Resources. (Vol. 43, Issue 3, p. 531–539). National Library of Medicine. https://doi.org/10.5851/kosfa.2023.e15
15. Zurbriggen, G. A., Maglietti, C. S., Pouzo, L. B., Testa, M. L., Riffel, S. L., Elizalde, J. C., & Pavan, E. (2022). Extending the feeding period beyond 8.0 mm of subcutaneous fat reduces feed efficiency without improving meat colour and tenderness of non-implanted feedlot steers. In Journal of Animal and Feed Sciences. (Vol. 31, Issue 4, pp. 1–11). Kielanowski Institute of Animal Physiology and Nutrition. https://doi.org/10.22358/jafs/151153/2022
16. Ugnivenko, A., Slobodyanyuk, N., Shtonda, O., Antoniuk, T., Pylypchuk, O., Karpovskyi, V., Kruk, O. (2021). Influence of the features of weight gain, age and direction of breed productivity on the quality parameters of beef. In Food Science & Technology. (Vol 15, Issue 1, pp. 108–116). Odesa National University of Technology. https://doi.org/10.15673/fst.v15i1.1963
17. Yu, H., Yu, S., Guo, J., Wang, J., Mei, C., Abbas Raza, S. H., Gong, C., & Zan, L. (2024). Comprehensive Analysis of Transcriptome and Metabolome Reveals Regulatory Mechanism of Intramuscular Fat Content in Beef Cattle. In Journal of Agricultural and Food Chemistry. (Vol 72, Issue 6, pp. 2911–2924). National Library of Medicine. https://doi.org/10.1021/acs.jafc.3c07844
18. JMGA. Beef carcass grading standart. Japan meat grading association. – (2000). Tokyo, Japan.

19. Commission Regulation (EC). 2008. Commission Regulation (EC) No 1249/2008 of 10 December 2008 laying down detailed rules on the implementation of the Community scales for the classification of beef, pig and sheep carcasses and the reporting of prices thereof.

20. DSTU ISO 1443:2005. Meat and meat products. General specifications. Quality management systems – Requirements.

21. DSTU ISO 936:2008. Meat and meat products. Method of determination of mass total ash. Quality management systems – Requirements.

22. DSTU ISO 1442:2005. Meat and meat products. Method of determining moisture content. Quality management systems – Requirements.

23. DSTU ISO 2917:2001. Meat and meat products. Determination of pH (control method). Quality management systems – Requirements.

24. Ugnivenko, A., Getya, A., Nosevych, D., Antoniuk, T., Kruk, O., Slobodyanyuk, N., Ivaniuta, A., Omelian, A., Gryshchenko, S., & Israelian V. (2022). The study of "muscle eye" in bulls of Ukrainian black-spotted dairy-meat breed as a factor in improving the properties of meat products. In Potravinarstvo Slovak Journal of Food Sciences. (Vol. 16. pp. 519–529). HACCP Consulting https://doi.org/10.5219/1762

25. Antoniuk, T. (2020). Technology of animal slaughter products. Methodical instruction and tasks for independent work for Bachelor Degree student of the specialty 204 – «Animal products Mamefacturing and processing technology». https://nubip.edu.ua/site/default/files/u249/tehnologiya_produktiv_zaboyu_tvarin.

26. Council Regulation (EC) No. 1099/2009 of September 24, 2009 on the protection of animals at the time of death.

27. Oler, A., Głowinska, B. & Młynek, K. (2015). Slaughter and carcass characteristics, chemical composition and physical properties of longissimus lumborum muscle of heifers as related to marbling class. In Archives Animal Breed. (Vol. 58, pp. 145–150). https://doi.org/10.5194/aab-58-145-2015

28. Ugnivenko, A., Kos, N., Nosevych, D., Mushtruk, M., Slobodyanyuk, N., Zasukha, Y., Otchenashko, V., Chumachenko, I., Gryshchenko, S. & Snizhko, O. (2022). The yield of adipose tissue and by-products in the course of the slaughter of inbred and outbred bulls of the Ukrainian beef breed. In Potravinarstvo Slovak Journal of Food Sciences. (Vol. 16, pp. 307–319). doi: https://doi.org/10.5219/1758

29. Zhou, M., Zhu, Z., Sun, H. Z., Zhao, K., Dugan, M. E., Bruce, H., Fitzsimmons, C., & Guan, L. L. (2022). Breed dependent regulatory mechanisms of beneficial and non-beneficial fatty acid profiles in subcutaneous adipose tissue in cattle with divergent feed efficiency. In Scientific Reports. (Vol. 12, Issue 1, pp. 4612–4628). https://doi.org/10.1038/s41598-022-08572-8

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

31. 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. In Potravinarstvo Slovak Journal of Food Sciences. (Vol. 17, pp. 997–1008). HACCP Consulting. https://doi.org/10.5219/1917

32. Kruk, O., Ugnivenko, A., Antoniuk, T., Kolisnyk, O., Slobodyanyuk, N., Nosevych, D., Naumenko, T., & Gruntkovskyi, M. (2024). Evaluation of beef carcass quality using the muscle eye area M. longissimus dorsi. Potravinarstvo Slovak Journal of Food Sciences. (Vol. 18, pp. 619–632). HACCP Consulting. https://doi.org/10.5219/1989

33. Smith, G.C., Carpenter, J.L., Cross, H.R., Murphey, C.E., Abraham, H.C., Savell, J.W., Parrish, F.C.Jr., Davis, G.W., & Berry, B.W. (1985). Relationship of USDA marbling groups to palatability of cooked beef. In Journal of Food Quality. (Vol. 7, Issue 4, pp. 289–308). Wiley Press Room. https://doi.org/10.1111/j.1745-4557.1985.tb01061.x

34. Lee, J. M., Choe, J. H., Park, H. K., Kim, Y. H., Park, B. Y., Kim, K. T., Koh, K.-Ch., Seo, S.-Ch., & Hwang, K. S. (2011). Effect of backfat thickness on the carcass grade factors and carcass price in Hanwoo cows and steers. In Food Science of Animal Resources. (Vol 31, Issue 2, pp. 280–289). Korea Institute of Science and Technology Information. https://doi.org/10.5851/kosfa.2011.31.2.280

35. Chi, N. T. K., Hue, P. T., Hanh, T. Q. & Ngoan, L. D. (2023). Carcass characteristics and meat quality of crossbred (Brahman× Lai Sind) and (Red Angus× Lai Sind) bulls kept in small scale farms. Online Journal of Animal and Feed Research. (Vol. 13, Issue 3, pp. 153–161). https://doi.org/10.51227/ojafr.2023.24

36. Batorska, M., Wiecek, J., Kunowska-Slosarz, M., Puppel, K., Slosarz, J., Golebiewski, M. & Balcerak, M. (2018). The effect of carcass weight on chemical characteristics and fatty acid composition of Longissimus

dorsi and Semimembranosus muscles of Eropean wild boar (Sus scrofa scrofa) meat. In Canadian Journal of Animal Science. (Vol. 98, Issue 3, pp. 557–564). Canadian Science Publishing. https://doi.org/10.1139/cjas-2017-0090

37. Rogoskii, I., Mushtruk, M., Titova, L., Snezhko, O., Rogach, S., Blesnyuk, O., Rosamaha, Y., Zubok, T., Yeremenko, O., & Nadtochiy, O. (2020). Engineering management of starter cultures in study of temperature of fermentation of sour-milk drink with apiproducts. In Potravinarstvo Slovak Journal of Food Sciences (Vol. 14, pp. 1047–1054). HACCP Consulting. https://doi.org/10.5219/1437

38. Brethour, J. R. (2004). The relationship of average backfat thickness of feedlot steers to performance and relative efficiency of fat and protein retention. In Journal of animal science, (Vol 82, Issue 11, pp. 3366–3372). Oxford University Press. https://doi.org/10.2527/2004.82113366x

39. 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. (Vol. 9, pp. 819605–819613). Frontiers. https://doi.org/10.3389/fvets.2022.819605

40. O'Quinn, T. G., Legako, J. F., Woerner, D. R., Kerth, C. R., Nair, M. N., Brooks, J. C., Lancaster J. M. & Miller, R. K. (2024). A current review of US beef flavor II: Managing beef flavor. In Meat Science. (Vol. 209. pp. 109403). Elsevier BV. https://doi.org/10.1016/j.meatsci.2023.109403

41. Beck, P.A., Beck, M.R., & Apple, J.K. (2022). Production systems and nutrition. Reference Module in Food Science. U.S. department of agriculture. https://doi.org/10.1016/B978-0-323-85125-1.00029-6

42. Im, C., Song, S., Cheng, H., Park, J., & Kim, G. D. (2024). Changes in meat quality and muscle fiber characteristics of beef striploin (M. longissimus lumborum) with different intramuscular fat contents following freeze-thawing. In LWT. (Vol 198, pp. 1–8). Elsevier BV. https://doi.org/10.1016/j.lwt.2024.116081

43. Hughes, J., Clarke, F., Li, Y., Purslow, P. & Warner, R. (2019). Differences in light scattering between pale and dark beef longissimus thoracis muscles are primarily caused by differences in the myofilament lattice, myofibril and muscle fiber transverse spacings. In Meat Science. (Vol. 149, pp. 96–106). Elsevier BV. https://doi.org/10.1016/j.meatsci.2018.11.006

44. Liu, T., Wu, J-P., Lei, Z-M., Zhang, M., Gong, X-Y., Cheng, S-R., Liang, Y., & Wang, J-F. (2020). Fatty Acid Profile of Muscles from Crossbred Angus-Simmental, Wagyu-Simmental, and Chinese Simmental Cattles. In Food Science Animal Resour. (Vol. 40, Issue 4, pp. 563–577). PubMed Central. https://doi.org/10.5851/kosfa.2020.e33

45. 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. In genes. In Genes (Basel). (Vol. 10, Issue 9, pp. 717). MDPI. https://doi.org/10.3390/genes10090717

46. 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. In Meat Science. (Vol 161, pp. 107954). Elsevier BV. https://doi.org/10.1016/j.meatsci.2019.10795

47. Ozdemir, V. F., Kocyigit, R., Yanar, M., Aydin, R., Diler, A., Palangi, V., & Lackner, M. (2024). An investigation of slaughter weight and muscle type effects on carcass fatty acid profiles and meat textural characteristics of young Holstein Friesian bulls. In Heliyon. (Vol 10, Issue 6, pp. 1–8). By Elsevier. https://doi.org/10.1016/j.heliyon.2024.e27

48. Baldassini, W. A., Chardulo, L. A. L., Silva, J. A. V., Malheiros, J. M., Dias, V. A. D., Espigolan, R., Baldi. F., Albuquerque, L. G., Fernandes. T., & Padilha, P. M. (2016). Meat quality traits of Nellore bulls according to different degrees of backfat thickness: a multivariate approach. In Animal Production Science. (Vol. 57, Issue 2, pp. 363–370). CSIRO Publishing. https://doi.org/10.1071/AN15120

49. Santana, M. H. A., Rossi Jr, P., Almeida, R., & Cucco, D. C. (2012). Feed efficiency and its correlations with carcass traits measured by ultrasound in Nellore bulls. In Livestock Science. (Vol. 145, Issue 1–3, pp. 252–257). Elsevier BV. https://doi.org/10.1016/j.livsci.2012.02.012

50. Warner, R. D. (2023). The eating quality of meat: IV – Water holding capacity and juiciness. In Lawrie's meat science. (pp. 457–508). Woodhead Publishing.

51. Bureš, D., Needham, T., Bartoň, L., Lebedová, N., Kotrba, R., Řehák, D., Kučerová, I., Klouček, P., & Hoffman, L. C. (2024). Consumer acceptance and quality of game meat "droëwors" sausages with different levels of added fat. In Meat Science. (Vol 210, pp. 109424). Elsevier. https://doi.org/10.1016/j.meatsci.2024.109424

52. Aaslyng, M. D. (2002). Quality indicators for raw meat. In Meat processing: Improving quality. 157–174. Book chapter.

53. Rahman, M. F., Iqbal, A., Hashem, M. A., & Adedeji, A. A. (2020). Quality assessment of beef using Computer Vision Technology. In Food Science of Animal Resources, (Vol 40, Issue 6, pp. 896–907). National Institutes of Health. https://doi.org/10.5851/kosfa.2020.e57

54. Vasyliv, V., Mushtruk, M., Zheplinska, M., Mukoid, R., & Tkachenko, S. (2021). Method of Electrohydraulic Activation of Water-Lime Suspension in Sugar Production. In Lecture Notes in Mechanical Engineering (pp. 664–673). Springer International Publishing. https://doi.org/10.1007/978-3-030-91327-4_64

55. Bal-Prylypko, L., Danylenko, S., Mykhailova, O., Nedorizanyuk, L., Bovkun, A., Slobodyanyuk, N., Omelian, A. & Ivaniuta, A. (2024). Influence ofstarter cultures on microbiological and physical-chemical parameters of dry-cured products. In Potravinarstvo Slovak Journal of Food Sciences. (Vol. 18, pp. 313–330). HACCP Consulting. https://doi.org/10.5219/1960

56. Palamarchuk, I., Mushtruk, M., Vasyliv, V., Stefan, E., Priss, O., Babych, I., Karpovych, I., & Pushanko, N. (2024). Modelling the centrifugal mixing process of minced meat to optimise the production of chopped meat semi-finished products. In Potravinarstvo Slovak Journal of Food Sciences. (Vol. 18, pp. 297–312). HACCP Consulting. https://doi.org/10.5219/1959

57. Vovkotrub, V., Iakubchak, O., Vovkotrub, N., Shevchenko, L., Lebedenko, T., Holembovska, N., Pylypchuk, O., & Omelian, A. (2024). Quality and safety of pork meat after cooling and treatment with lactic starters. In Potravinarstvo Slovak Journal of Food Science. (Vol 18, pp. 439–452). HACCP Consulting. https://doi.org/10.5219/1954

58. Ferreira, G. A., Barro, A. G., Terto, D. K., Bosso, E. B., Dos Santos, É. R., Ogawa, N. N., & Bridi, A. M. (2024). Sensory quality of beef with different ultimate pH values Brazilian perspective. In Meat Science. (Vol 209, 109415). National Institutes of Health. https://doi.org/10.1016/j.meatsci.2023.109415

59. 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. In Journal of Proteomics. (Vol 278, pp. 104871). By Elsevier. https://doi.org/10.1016/j.jprot.2023.104871

60. Mushtruk, M., Palamarchuk, I., Palamarchuk, V., Gudzenko, M., Slobodyanyuk, N., Zhuravel, D., Petrychenko, I., & Pylypchuk, O. (2023). Mathematical modelling of quality assessment of cooked sausages with the addition of vegetable additives. In Potravinarstvo Slovak Journal of Food Sciences (Vol. 17, pp. 242–255). HACCP Consulting. https://doi.org/10.5219/1845

61. Pacheco, R. F., Machado, D. S., Restle, J., Sartori, D. B. S., Costa, P. T., & Vaz, R. Z. (2024). Metanálise da qualidade da carne de bovinos abatidos com diferentes espessuras de gordura subcutânea. In Pesquisa Agropecuária Brasileira. (Vol. 58, e03110, pp. 1–9). SciELO Brasil. https://doi.org/10.1590/S1678-3921.pab2023.v58.03110

62. 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? In Animal. (Vol. 14, Issue 6, pp. 1204–1212). Springer International Publishing. https://doi.org/10.1017/s1751731119003422

63. Eun-Young Jung, Young-Hwa Hwang & Seon-Tea Joo. (2016). The Relationship between Chemical Compositions, Meat Quality, and Palability of the 10 Primal Cuts from Hanwoo Steer. In Korean journal for food science of animal resources. (Vol. 36, Issue 2, pp. 145–151). PubMed Central. https://doi.org/10.5851/kosfa.2016.36.2.145

64. Troy, D. J., Tiwari, B. K., & Joo, S. T. (2016). Health implications of beef intramuscular fat consumption. In Korean Journal for Food Science of Animal Resources. (Vol 36, Issue 5, pp. 577–582). PubMed Central. https://doi.org/10.5851/kosfa.2016.36.5.577

65. Ponnampalam, E. N., Priyashantha, H., Vidanarachchi, J. K., Kiani, A., & Holman, B. W. B. (2024). Effects of Nutritional Factors on Fat Content, Fatty Acid Composition, and Sensorial Properties of Meat and Milk from Domesticated Ruminants: An Overview. In Animals. (Vol 14, Issue 6, pp. 840–879). Springer International Publishing. https://doi.org/10.3390/ani14060840

66. Kruk, O., & Ugnivenko, A. (2024). The area of loin eye in bulls of the Ukrainian Black-and-White dairy breed and its relationship with beef characteristics. In Animal Science and Food Technology. (Vol. 15, Issue 2, pp. 93–106). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/animal.2.2024.93

67. Li, X., Fu, X., Yang, G., & Du, M. (2020). Review: Enhancing intramuscular fat development via targeting fibro-adipogenic progenitor cells in meat animals. In Animal. (Vol. 14, Issue 2, pp. 312–321). Elsevier BV. https://doi.org/10.1017/s175173111900209x

68. Kryzhova, Y., Slobodianiuk, N., & Moskalenko, I. (2023). Application of modern technologies to improve the quality of sausage products. In Animal Science and Food Technology. (Vol. 14, Issue 1, pp. 49–64). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/animal.1.2023.43

69. Riabovol, M. V. & Bal-Prylypko, L. V. (2021). Justification and development of sausage technology with health properties. In Animal Science and Food Technology. (Vol. 12, Issue 1, pp. 39–47). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/animal2021.01.039

70. Nikolaenko, M.S. (2021). Optimization of the technology of production of functional semi-finished meat products covered in pastry. In Animal Science and Food Technology. (Vol. 12, Issue 1, pp. 19–27). National University of Life and Environmental Sciences of Ukraine. https://dx.doi.org/10.31548/animal/2021.01.019

71. Filin, S., Bal-Prylypko, L., Nikolaenko, M., Holembovska, N., & Kushnir, Yu. (2023). Development of technology for plant-based minced semi-finished products. In Animal Science and Food Technology. (Vol. 14, Issue 2, pp. 100–112). National University of Life and Environmental Sciences of Ukraine. https://doi.org/10.31548/animal.2.2023.100

72. Mushtruk, M., Palamarchuk, I., Palamarchuk, V., Gudzenko, M., Slobodyanyuk, N., Zhuravel, D., Petrychenko, I., & Pylypchuk O. (2023). Mathematical modelling of quality assessment of cooked sausages with the addition of vegetable additives. In Potravinarstvo Slovak Journal of Food Sciences. (Vol 17, pp. 242–255). HACCP Consulting. https://doi.org/10.5219/1845

73. Bal-Prylypko, L., Nikolaenko, M., Kanishchev, O., Beyko, L., & Holembovska, N. (2023). Improving the technology for the production of raw dried beef products. In Animal Science and Food Technology. (Vol. 14, Issue 4, pp. 26–39). ResearchGate BV. https://doi.org/10.31548/animal.4.2023.26

74. Mushtruk, M., Mushtruk, N., Slobodyanyuk, N., Vasyliv, V. & Zheplinska, M. (2024). Enhanced energy independence: converting animal fat into biodiesel. In International Journal of Environmental Studies. (Vol. 81, Issue 1, p. 1–11). ResearchGate BV. https://doi.org/10.1080/00207233.2024.2314860

75. 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. In Animals. (Vol. 11, Issue 3, p. 870). Springer International Publishing. https://doi.org/10.3390/ani11030870

76. Park, S. J., Beak, S.-H., Jung, D. J. S., Kim, S. Y., Jeong, I. H., Piao, M. Y., Kang, H. J., Fassah, D. M., Na, S. W., Yoo, S. P., & Baik, M. (2018). Genetic, management, and nutritional factors affecting intramuscular fat deposition in beef cattle – A review. In Asian-Australasian Journal of Animal Sciences. (Vol. 31, Issue 7, pp. 1043–1061). Asian Australasian Association of Animal Production Societies. https://doi.org/10.5713/ajas.18.0310

Funds:

The study was conducted within the framework of the academic research work “To substantiate systems of production and monitoring of safe animal husbandry products” funded by the state budget of Ukraine (state registration number: 0121U110192).

Acknowledgements:

We would like to thank you to Dr. for Anatolii Ugnivenko.

Conflict of Interest:

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.

Contact Address:

Olha Kruk, National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Milk and Meat Production Technologies, Heroiv Oborony St., 15, 03041, Kyiv, Ukraine

E-mail: olgakruk2016@ukr.net

ORCID: https://orcid.org/0000-0001-9975-8994

Anatolii Ugnivenko, National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Milk and Meat Production Technologies, Heroiv Oborony St., 15, 03041, Kyiv, Ukraine
E-mail:ugnivenko@nubip.edu.ua
ORCID: https://orcid.org/0000-0001-6278-8399

Dmytro Nosevych, National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Milk and Meat Production Technologies, Heroiv Oborony St., 15, 03041, Kyiv, Ukraine
E-mail: dknosevvich@i.ua
ORCID: https://orcid.org/0000-0003-2495-2084

Oleksandr Natalich, National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Milk and Meat Production Technologies
Heroiv Oborony St., 15, 03041, Kyiv, Ukraine
E-mail: oleksandrnatalich@gmail.com
ORCID: https://orcid.org/0000-0003-3245-6179

Mykola Gruntkovskyi, National University of Life and Environmental Sciences of Ukraine, Faculty of Livestock Raising and Water Bioresources, Department of Technologies in Poultry, Pig and Sheep Breeding, Heroiv Oborony str., 15, Kyiv, 03041, Ukraine
E-mail: kolya_gr26@ukr.net
ORCID: https://orcid.org/0000-0002-6969-2987

Iryna Kharsika, National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Control of Agricultural Products, Department of Technologies of Meat, Fish and Seafood, Polkovnyka Potiekhina Str., 16, 03121, Kyiv, Ukraine
E-mail: veretynska23@ukr.net
ORCID: https://orcid.org/0000-0002-2789-7757

Oleksandr Androshchuk, National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Management of Agricultural Products, Department of Technologies of Meat, Fish and Marine Products, Heroiv Oborony Str., 15, 03041 Kyiv, Ukraine
E-mail: testoo@ukr.net
ORCID: https://orcid.org/0009-0002-3713-5278

***Inna Stetsiuk**, National University of Life and Environmental Sciences of Ukraine, Faculty of Food Technology and Quality Control of Agricultural Products, Department of Technologies of Meat, Fish and Marine Products, Vystavkova Str., 16, studying building No 12, Kyiv, 03041, Ukraine
E-mail: Stetsyukinna8513@ukr.net
ORCID**:** https://orcid.org/0000-0001-8392-6527

Corresponding author: *