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The study of "muscle eye" in bulls of Ukrainian black-spotted dairy-meat breed as a factor in improving the properties of meat products

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ABSTRACT
The impact of age, live weight, and growth rate of the bulls of Ukrainian breeds on the area of "muscle eye" (cross-section of *m. longissimus dorsi* when the carcass is divided into front and rear between the 12th and 13th ribs) was studied. The correlation between the size of the "muscle eye" and the carcass's characteristics and the meat's qualitative indicators was also determined. The research was conducted on the bulls of Ukrainian black-and-white dairy (UBWDB) and Ukrainian meat (UMB) breeds. Living animals "muscle eye" area was determined with the ultrasonic analyser Emperor 860, after slaughter. It was found that UMB bulls have the area of "muscle eye" twice as big as their UBWDB peers. The "muscle eye" area increases when growing the cattle to 400 – 450 kg. In the future, it will be practically independent of the age and weight of the animals and remains stable. An increase in the average daily gains within the breed leads to an increase in the "muscle eye" area. The area of "muscle eye" has a weak negative connection (r = -0.193) with meat tenderness and dry matter content (r = -0.345) and a positive one with slaughter weight (r = 0.614) and slaughter yield (r = 0.653). Of the three parameters (length, depth, and area) of "muscle eye", the greatest impact on the technological properties of meat has depth. Its increase has a negative connection with meat tenderness (r = -0.810) and moisture (r = -0.474), but it has a positive impact on the moisture retention capacity (r = 0.338) and weight of weighed portion after heat treatment. The obtained results can be used to clarify the optimal growing parameters of the bulls of Ukrainian black-and-white dairy and meat breeds for meat and determine the optimal age and live weight of the cattle slaughter.

Keywords: beef, live weight, carcass weight, meat boiling, "muscle eye"

INTRODUCTION
The share of the valuable cuts of the beef carcass impacts on the final cost of products. Direct determination of their yield in each animal has technological difficulties and is not used during lifetime assessment **[1]**. One of the features that are directly related to the yield of the valuable cuts of the carcass is the area of the "muscle eye" of *m. longissimus dorsi* is used due to the connection with the consumer and nutritional characteristics of the beef products **[2]**, **[3]**. The area of the "muscle eye" varies depending on the breed and race of the animal **[2]** as well as the intramuscular fat content **[4]**. The area of the "muscle eye", measured by ultrasound in young cattle, is rather closely (r = 0.80) correlated with the weight of the muscle tissue in the carcass, including the highest grade (r = 0.69) **[5]**. The data concerning the area of "muscle eye" of *m. longissimus dorsi*, obtained by ultrasound, are used **[5]**, **[6]** to predict the obtained beef amount and belonging to a certain grade. The heritability ratio of the "muscle eye" area is 0.45 **[7]**. Among the carcasses of the same weight and fat content, an increase in the area of this muscle in the split indicates an increase in the yield of the cuts. The larger the "muscle eye" area, the greater the weight of steaks that have the highest cost during a retail sale **[8]**.

In Ukraine, the principal amount of beef is obtained from the slaughter of dairy cattle and an insignificant one - from the slaughter of specialized meat animals. The most common of the dairy breeds are the Ukrainian black-and-white dairy breed. Due to their biological properties, these animals can be intensively raised for meat up to

a live weight of 500 – 600 kg. A significant role in solving the beef deficit problem should be played by the cattle of the Ukrainian meat breed **[9]**, **[10]**. This is a promising local breed characterized by large sizes and rapid growth. The data of the area of "muscle eye" of *m. longissimus dorsi* in these breed animals and its connection with the quantitative and qualitative characteristics of the beef is not enough yet.

Scientific Hypothesis

The "muscle eye" area (cross-section of *m. longissimus dorsi* when the carcass is divided into front and rear between the 12th and 13th ribs) is directly related to the yield of the valuable cuts of the carcass and can be estimated during the lifetime. Therefore, it was decided to study the impact of age, live weight, and growth rate of the bulls of Ukrainian breeds on the area of the "muscle eye" as well as to determine the correlation between the size of the "muscle eye" and the characteristics of the carcass and the qualitative indicators of the meat for determining the value of the carcass.

MATERIAL AND METHODOLOGY

Sample

The research objects were the bulls of Ukrainian black-and-white dairy (UBWDB) and Ukrainian meat (UMB) breeds.

Animals and Biological Material

The research was conducted on the bulls of Ukrainian black-and-white dairy (UBWDB) and Ukrainian meat (UMB) breeds.

Instruments

Ultrasonic device (Emperor 860, Vinno 6, China).
Warner-Bratzler device (Lab Logistic Group GmbH, Germany).
Electronic analytical scale (KERN ABS 120-4, SE "Khimtex", Ukraine).
Laboratory ruler (ElizLabs 68933, Ukraine)
Measuring tape (Schweikin, Ukraine).

Laboratory Methods

The area of "muscle eye" was calculated by formula (1):

$$S = a \times b \times 0.8 \quad (1)$$

Where:
S – is the area of "muscle eye", cm^2; a – is the length of "muscle eye", cm; b – is the depth of "muscle eye", cm; 0.8 – is the ratio.

The carcass weight, the length of thigh and carcass, and the thigh circumference **[11]**. The meat tenderness, moisture retention capacity, and boiling were assessed during the heat treatment.

The carcass front (l_1) length was measured from the front point of the aitch-bone (at the cutting) to the middle of the front edge of the first rib. The thigh length (l_2) was measured from the highest point of the hocks to the extreme front point of the aitch bone at the cutting. The carcass length ($l_1 + l_2$) was measured by the sum of the length of the carcass front and the thigh length. The thigh circumference (b - b) was measured in the plane deviated by 60 degrees from the measurement line of the thigh length and perpendicular to this line. According to these indicators, the fleshing index (ratio of carcass weight to its length – K_1) and the thigh fullness ratio (ratio of thigh circumference to its length – K_2) were calculated.

The raw meat tenderness was determined with the help of the Warner-Bratzler device by the effort required to cut the meat sample of 0.15 kg **[8]**. The meat samples 25 mm thick were extracted from *m. longissimus dorsi* in the area of the 12th – 13th ribs. The samples were cut from the fat and bones. The force acting on the knife was calculated by the formula (2):

$$P_2 = \frac{v \times t \times l_1}{l_2} \quad (2)$$

Where:
P_2 – is the knife force at the cutting end (kg); v – is the fraction eruption rate (g.sec.); t – is the cutting time calculated on the electronic stopwatch; l_1 – is the distance from the center of the receiving box to the axis; l_2 – is the distance from the knife to the axis.

The bound water content determined the moisture retention capacity of meat to the meat weight by the percentage. The bound moisture content was determined by a "press method" by the amount of water released from the meat under the action of light pressing and absorbed into the filter paper, forming a wet spot. The spot area size depends on the capacity of the meat to hold water. The better the moisture retention capacity, the smaller the wet spot. The total area of the spot (S_2), which is formed under the pressed meat and the released moisture absorbed by the filter paper (S_1), was determined with the help of the planimeter. The area of the wet spot (A) was determined by the difference between the total area of the spot (S_2) and the area of the occupied meat (S_1). An integral rectangular sample weighing 0.15 kg was cut from *m. longissimus dorsi* to determine the residual meat weight after the heat treatment (boiling). The samples were weighed on technical scales with an accuracy of 0.01 g, then placed in a pan with 4 – 5 liters and poured with 2 – 3 liters of cold distilled water. The pan was placed on the stove. Water was brought to a boil and boiled for 1.5 hours. Then the sample was removed from the water, cooled to 20 °C, and weighed. The meat boiling was determined by formula (3):

$$Sm = \frac{Cm \times 100}{Rm} \tag{3}$$

Where:
Sm – is the meat shrinkage, %; *Cm* – is the weight of boiled meat, g; *Rm* – is the weight of the raw sample, g.

The bound water content in meat was determined by formulas (4, 5):

$$B = \frac{(W - 8.4 \times S) \times 100}{M} \tag{4}$$

$$B_1 = \frac{(W - 8.4 \times S) \times 100}{W} \tag{5}$$

Where:
B – bound moisture content to meat weight, %; B_1 – bound moisture content to total moisture content, %; *W* – moisture content in weighed portion, mg; *S* – an area of a wet spot, cm^2; M – weighed portion of meat, mg.

Description of the Experiment

Sample preparation:

The research was conducted on the bulls of Ukrainian black-and-white dairy (UBWDB) and Ukrainian meat (UMB) breeds (Figure 2). The impact of age, live weight, and growth rate of the bulls of Ukrainian breeds on the area of the "muscle eye" were studied, as well as the correlation between the size of the "muscle eye" and the characteristics of the carcass and the qualitative indicators of the meat were determined for determining the value of the carcass. Cattle were bred in the village of Kalynivka, Cherkasy region.

Figure 1 Ukrainian meat breeds.

Number of samples analyzed: 27 samples of Ukrainian black-and-white dairy breed (UBWDB) and 12 samples of Ukrainian meat breed (UMB) were analyzed to determine the area of "muscular eye" of the bulls depending on the slaughter age. 36 samples of UBWDB and UMB were analyzed to determine the area of "muscle eye" of the bulls, depending on live weight before slaughter. 27 samples of UBWDB and 10 samples of UMB were analyzed to determine the area of the "muscle eye" of the bulls, depending on the growth rate.

Number of repeated analyses: 3.

Number of experiment replication: 2.

Design of the experiment: UBWDB bulls were held in groups of 25 heads from birth to 4 months. They consumed 547 kg of whole milk during this period and 182 kg of skim milk. Further completion of growing of the animals was carried out at the feedlot. During the period from birth to 20 and 22 months of age, each bull consumed 31.486 and 36.120 MJ of metabolizable energy, respectively. The feed consumption was as follows: coarse 12.3 and 12.4%, juicy 14.3 and 14.3, green 27.8 and 28.4, concentrated 18.4 and 18.8%. The bull slaughter was carried out in a slaughterhouse (Kalynivka village).

The bulls of the Ukrainian meat breed were held with their mothers on suction from birth to ex-communication. From the age of 14 days, they were additionally fed with the concentrated feed. At 8 months, the animals were tested for their productivity, which lasted until they reached 22 months of age. During the period from 8 to 20 months and from 8 to 22 months, each bull consumed the feed with an energy value of metabolizable energy of 24.697 and 26.243 MJ, respectively. The animal slaughter was carried out at the Cherkasy meat-packing plant.

The area of the "muscle eye" was determined during the animal life using the ultrasonic investigation (ultrasound) and after slaughter. The animals were fixed in the slaughter machine. The hair was cut to a hair length of max 1.5 cm in the study area. In order to provide the maximum sensor and skin contact, vegetable oil was applied to the measurement site before scanning. The temperature of the oil applied to the skin was above 20 °C. Under temperatures below 8 °C, the oil containers were heated in a water bath. The device was installed between the 12^{th} and 13^{th} ribs of the animals to measure the area of the "muscle eye".

The live weight of each animal was determined within ±7 days from the scanning date. The animals were slaughtered within 24 – 48 hours after the ultrasound. After slaughtering on the cross-section of *m. longissimus dorsi*, where the carcass is divided into front and rear between the 12^{th} and 13^{th} ribs, the length and depth of the "muscle eye" were measured using the ruler according to the scheme shown in Figure 2.

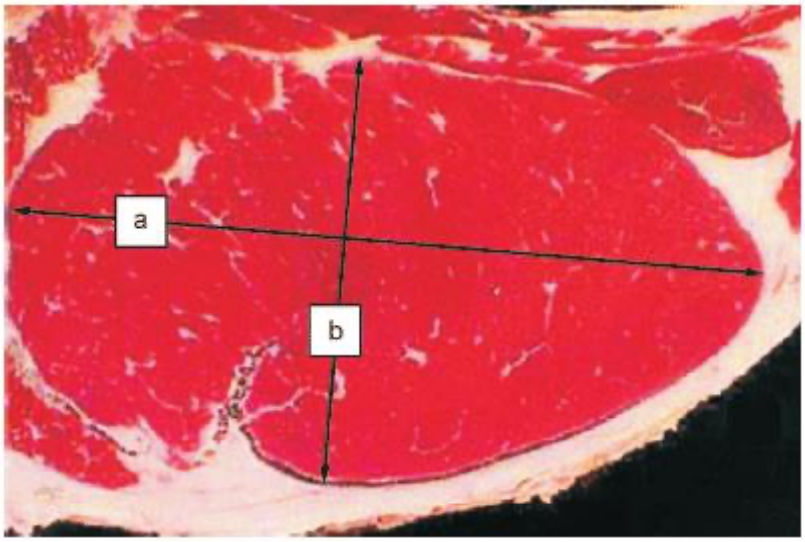

Figure 2 Length (a) and depth (b) of "muscle eye".

Statistical Analysis

The statistical analysis of the results was carried out according to common methods. The arithmetic means with the statistical error, and the reliability criteria were determined. Pearson's correlation coefficient was determined when the correlation analysis was carried out. The statistical analysis data were produced by Microsoft excel and Statistica 15. The accuracy of the obtained experimental data was determined using the Student's test for a confidence probability of ≤0.05 based on the number of parallel determinations at least 5. Linear programming problems were solved using the MS Excel spreadsheet processor "Search for a solution" setting (Excel Solver).

RESULTS AND DISCUSSION

The "muscle eye" area significantly depends on the breed and direction of animal productivity. This feature in the animals of the Ukrainian meat breed is approximately 2 times greater (p <0.001) than in the peers of the Ukrainian black-and-white dairy breed 1).

Table 1 Area of "muscle eye" of bulls, depending on slaughter age, m^2.

Slaughter age, months	UBWDB		UMB	
	n	M ±m	n	M ±m
20	11	0.006529 ±4.07	6	0.01354 ±7.6***
22	16	0.00686 ±4.38	6	0.01335 ±6.9***

Note: ***) p <0.001.

A long-term purpose selection forms this feature of the Ukrainian meat breed. By the area of "muscle eye", the bulls of Ukrainian meat breed significantly predominate the animals of other breeds, not only the dairy productivity. Thus, the average area of "muscle eye" in 30-month-old bulls of the Korean breed (Hanvoo) is 87.4 cm^2 **[6]**. The increase in the slaughter age from 20 to 22 months did not practically impact the bulls' area of "muscle eye", both Ukrainian black-and-white dairy and Ukrainian meat breeds. This result suggested that the transverse growth of *m. longissimus dorsi* is suspended for a certain ontogenesis period, so further animal growth does not impact the area of the "muscle eye". This assumption is confirmed by analyzing the area of the "muscle eye", depending on the live weight of the animals before slaughter (Table 2).

Table 2 Area of "muscle eye" of bulls, depending on live weight before slaughter, m^2.

Live weight, kg	UBWDB		UMB	
	n	M ±m	n	M ±m
350 to 400	12	0.005529 ±2.31	-	-
401 to 450	15	0.0073 ±3.41**	2	0.01342 ±7.10
451 to 500	5	0.00843 ±4.74**	3	0.01372 ±6.82
more than 500	4	0.0072 ±6.78	7	0.013269 ±6.41

Note: **) p <0.01 compared to the animals with a live weight of 350 to 400 kg.

The area of "muscle eye" of UBWDB bulls slaughtered with a live weight of 401 – 450 kg was 32% more than the area of "muscle eye" of the animals with a live weight of 350 – 400 kg. Subsequently, when the live weight of the animals of this breed is increased, the increased tendency of the area of the "muscle eye" was not sufficiently pronounced. Thus, *m. longissimus dorsi* of UBWDB bulls is significantly increased in diameter until they reach a live weight of 400 – 450 kg, after which its growth slows down.

In UMB animals slaughtered with a live weight of 401 kg or more, the difference in the area of "muscle eye was not found. It also confirms the previous conclusion about the suspension of transverse growth of *m. longissimus dorsi*, after reaching a live weight of 400 – 450 kg by the bulls.

The results between the ultrasonic investigation of the live animals and the determination of the "muscle eye" area on the carcass were used to verify the assessment accuracy of the "muscle eye" area. According to ICAR recommendations **[12]**, the difference between the scanning results and the average carcass assessment should be minimal, and the correlation coefficients between them should be at least 0.8. The study results of UBWDB bulls with different live weights show that the ultrasound's lifetime assessment of the area of the "muscle eye" is a reliable criterion with high recurrence after slaughter. According to our data, the average difference between the ultrasound prediction and post-slaughter assessment is 0.053 m^2 at 22 months and 0.058 m^2 at 20 months. A close correlation characterizes both determination methods. Thus, the correlation coefficients are 0.99 for the live weight of the bulls from 401 to 450 kg and 0.92 from 451 to 500.

The area of the "muscle eye" of *m. longissimus dorsi* depends on the growth rate of the animals from birth to slaughter (Table 3).

Thus, the area of the "muscle eye" of UBWDB and UMB bulls increases with increasing the average daily gains of live weight from birth to slaughter. An increase in the growth rate of UBWDB animals by 0.15 – 0.20 kg contributes to an increase in the area of the "muscle eye" by 35% (p <0.01).

A similar tendency was found for UMB. With the average daily gain of more than 0.1 kg, the bulls of this breed had the area of the "muscle eye" greater by 9%. Thus, an increase in the growth rate of young animals, which improves the protein deposition in the muscle tissue, is the main way to impact on the area of the "muscle eye" within the breed without using the selection methods.

Table 3 Area of "muscle eye" of bulls, depending on the growth rate, m^2.

Average daily gain, g	UBWDB		UMB	
	n	M ±m	n	M ±m
up to 550	9	0.00571 ±4.17	-	-
551 – 600	10	0.00688 ±5.27	-	-
651 – 700	8	0.00771 ±4.53**	-	-
701 – 800	-	-	5	0.012969 ±7.24
801 – 900	-	-	5	0.014119 ±8.00

Note: **) p <0.01 compared to a gain of up to 0.55 kg.

The area of the "muscle eye" of *m. longissimus dorsi* is positively correlated with the slaughter weight and yield. Its increase contributes to increased carcass weight ratio to its length, indicating its best musculature development (Table 4).

The positive correlations between the "muscle eye" area and the pre-slaughter live weight and carcass weight are also typical for other breeds. In particular, such results were found in Hanvoo bulls **[13]**. The positive correlation of "muscle eye" with the slaughter weight (of carcass) can be explained by the fact that *m. longissimus dorsi* presents the two most valuable cuts of the carcass: lumbar and dorsal, which are the significant part of the muscle tissue in the carcass.

The "muscle eye" area is weakly correlated with the length of the carcass and thigh, and its increase partially contributes to a decrease in meat tenderness **[14]**. Its intramuscular fat content significantly affects meat tenderness **[15]**. Optimal distribution in the muscle tissue improves this valuable technological property.

Among the carcass characteristics, the increase in the "muscle eye" area in the section indicates only an increase in the cut yield. It does not predict the assessment of the beef quality in the meat animals **[16]**, **[17]**. The "the muscle eye" area does not correlate with the moisture retention capacity. This indicates that its increase does not lead to changes in the beef properties to hold moisture, depending on the quality of many meat products produced from these raw materials: taste, aroma, juiciness, hardness, and quality of sausage products **[18]**, **[19]**. These beef properties can be improved by increasing the level of the intramuscular fat to the optimal values. The beef of older animals contains more intramuscular fat **[20]**, **[21]**. The carcasses with lower fat content are obtained from the bulls than oxen **[22]**, **[23]**, **[24]**.

Table 4 Correlation coefficients (r) between measurements of "muscle eye" of *m. longissimus dorsi* and quantitative and qualitative characteristics of carcasses (n = 12).

Carcass feature	"Muscle eye" features		
	length	depth	area
Slaughter weight	0.229	0.168	0.614
Slaughter yield	0.058	0.140	0.653
Moisture retention capacity of meat	0.167	0.338	-0.037
Meat boiling	0.047	0.451	0.000
Moisture content in meat	0.273	-0.474	0.094
Dry matter content in meat	-0.221	0.109	-0.345
Meat tenderness	-0.226	-0.810	-0.193
Cutting time	0.365	0.216	0.056
Carcass length ($l_1 + l_2$)	-0.169	-0.422	0.197
Thigh length (l_2)	0.167	0.348	0.220
Thigh circumference (b - b)	0.306	0.094	0.094
Meat spot (S_1)	-0.291	-0.151	0.04
Wet spot (S_2)	-0.333	-0.168	0.052
General spot (A)	0.211	-0.110	0.345
Bound moisture content to weight of the weighed portion of meat (M)	0.332	0.146	-0.235
Bound moisture content to general moisture (D)	-0.307	-0.173	-0.018
The ratio of slaughter weight (of carcass) to its length (K_1) Fleshing index	0.563	-0.038	0.659
The ratio of thigh circumference to its length (K_2) Thigh fullness ratio	-0.235	0.596	-0.354

Since the area of the "muscle eye is positively correlated with the quantitative characteristics of the beef, but not with qualitative ones, and the intramuscular fat content is, on the contrary, then in many countries, the area of the "muscle eye" is complemented by marbling in the assessment methods of the cattle **[25]**, **[26]**. Thus, beef marbling is included in its quality determination system according to the system of USDA **[7]**, EUROP, IMCA, and **[27]**, **[28]**. Unlike the area of the "muscle eye", other indicators, in particular its depth, have a more significant impact on the technological properties of meat. It was found that an increase in the depth of *m. longissimus dorsi* on the cross-section of UMB bulls leads to a rise in the meat hardness, decrease in its moisture, an increase in the moisture-retaining properties, and reduce in the weight loss during the heat treatment. The main reason for these properties of meat can be an increase in the diameter of the muscle fibres, due to which the depth of the "muscle eye" increases **[29]**, **[30]**, **[31]**. Recently, the demand for lean and biologically complete beef has been growing. To obtain such meat in the required amount in Ukraine, it is advisable to attach great importance to the animals of the Ukrainian meat breed **[32]**, **[33]**, **[34]**. Its bulls at the age of 20 and 22 months have only 0.6 and 0.5% internal fat content. The market requirements are more consistent with the Ukrainian meat breed, which responds to satisfactory feeding with the rapid growth of the muscle tissue and the late formation of the fat. The biological feature of this cattle is that its weight gain up to 20 – 22 months of age is mainly due to the accumulation of muscle tissue and moderate fat content. The beef of these cattle should be considered lean, and it is in great demand **[35]**, **[36]**, **[37]**. As a result, it has a high moisture retention capacity and low weight losses during the cooking procedure.

CONCLUSION

The area of the "muscle eye" of *m. longissimus dorsi* intensively increases in the bulls to a live weight of 400 – 450 kg, it is significantly influenced by the average daily gains. By the area of "muscle age" the animals of Ukrainian meat breed are twice as large as their peers of Ukrainian black-and-white dairy breeds. Quantitative signs of the carcass can be predicted by the area of the "muscle eye", the qualitative characteristics of the beef are very weak. A number of the technological properties of meat, in particular tenderness, moisture, moisture retention capacity, and weight loss during the heat treatment, are affected by the depth of *m. longissimus dorsi* on the cross section.

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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.

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