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Relationship between the live assessment of Holstein-Friesian bulls and beef breed crosses, and the post-mortem objective evaluation of beef carcasses

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Abstract: *Relationship between the live assessment of Holstein-Friesian bulls and beef breed crosses, and the post-mortem objective evaluation of beef carcasses.* Methods of assessing the slaughter and fattening characteristics of live cattle are a common and inseparable element of breeding work, but the commonly used visual assessment methods are not fully objective. Nowadays, innovative methods for the computer image analysis of beef carcasses, which are usually precise and objective than methods and are often used. The aims of this study was to determine the relationship between live assessment and post-mortem analysis for the objective evaluation of carcasses, and to determine if it is possible to predict carcass quality based on live measurements. The material consisted of bulls that were Holstein Friesian breed (N=128), and beef breed crosses (N =170). The experiments included the zoometric measurement of the bulls and the results of an objective evaluation of the carcasses using computer image analysis. In terms of the beef breed crosses all live measurements were significantly correlated ($P < 0.05$) with the post-slaughter values. The coefficients of determination (R^2) were higher for crossbreed bulls than for dairy bulls by over 20% in the case of the distance between the heel and the shoulder and for hind quarter volume. In both research groups an increase in height at the withers resulted in a body conformation of(standardized regression coefficients –ß) 0.68 and 1.006, for pure breed and beef breed crosses respectively. Live cattle measurements – especially measurements performed on beef breed crosses, may forecast selected characteristics in beef carcasses.

Key words: beef carcass, bull, beef breed crosses, objective evaluation, live assessment

INTRODUCTION

Methods of assessing the slaughter and fattening characteristics of live cattle constitute a basic and inseparable element of breeding work, as well as being the basis for perfecting the particular parameters of the animals (Nogalski et al. 2017). They also allow for the early selection of the proper animals, the prediction of their predisposition for a specific fattening system, as well as forecasting animal slaughter value. On the other hand, Koknaroglu et al. (2005) reported that fattening performance is affected by housing type, season, initial weight, sex, and cattle pen population. Properly determining the slaughter value is also an important tool for cattle breeders and meat processing plants in order to properly determine the price for the animals provided for slaughter (Węglarz et al. 2013). The methods generally used for assessing live cattle consist of, for example, a visual assessment and a so called manual estimation, which to large degree depends on the experience and subjectivity of the person carrying out the assessment. In some case a more precise assessment of live cattle may be achieved by taking advantage of zoometric measurements with the use of a zoometric stick, compass, or measuring tape. These methods are used to assess fattening efficiency, and most importantly to determine approximately which EUROP class the cattle will be purchased in, and thereby determine the estimated profit. The system currently used for classifying animal carcasses is obligatory for EU member states under the European Union Commission Regulation (EC) 1249/2008. The EUROP system consists of five classes conformation and fatness, each with three subclasses. This system is a visual assessment performed by a person who classifies the quality of cattle carcasses and assigns them to classes. Just as with the visual live assessment, this system also depends on the classifying person, and may result in inadequately assigning the carcass to a specific class in reference to its quality (Wnęk et al. 2015). In order to improve the assessment, research has been initiated that will search for objective classification methods, which, additionally, allows the tissue composition of the carcass as well as, for example, such properties(depending on needs) as the volume of the quarter carcass or side, to be predicted (Słoniewski and Sakowski 2000, Wnęk et al. 2016).

The latest technologies used in meat processing plants tend to eliminate the subjective elements of classification and increase the precision and repeatability of post-slaughter animal carcass assessments. VIA – visual image analysis – is widely used around the world as well as within the European Union. It involves photographing the carcasses of slaughtered animal and then, based on the photos, making an assessment of their quality using a computer program. Some models for assessing beef carcasses take both 2D and 3D photos, which increases the precision of the measurements being performed. These technologies describe the quality of the carcass in accordance with the legal and trade requirements of a given country, but can also determine other quality parameters of the carcass, such as primal cuts' weight, the quantity of meat and fat within the carcass, estimating the scale of damage to a carcass, as well as the meat and fat's colour, which are important in terms of genetically perfecting these populations. The software also allows for a statistical analysis and the archiving of data (Pipek et al. 2005). Cross et al. (1983) and Wassenberg et al. (1986) performed one of the first research tests using the VIA technology in order to assess its efficiency in objective carcass classification for academic and commercial purposes. Both teams confirmed a better or at least equal precision for this method, in determining the muscle content of a carcass in reference to the work of qualified classification workers. The results coming from an objective assessment of beef carcasses, mainly VIA, in the post-slaughter classification, have also been confirmed (Cross et al. 1983, Wassenberg et al. 1986). The accurate functioning of the computer image analysis is possible thanks to the high correlation (r = 0.62–0.79) between slaughter characteristics such as body weight, cold carcass weight, weight of primal cuts, and meat weight in primal cuts; and animal body dimensions such as diagonal body length, body circumference area of the animal carcass' side, leg side area, and shoulder width (Sakowski et al. 1996). In some countries, purchasing live animals from breeders and selling cattle to meat processing plants is mostly handled by agents. Cattle breeders make a profit from live animals while it is the agents who most often 'appraise' the animals based on a visual assessment and their weight. Meat processing plants purchase cattle based on the carcass, which is appraised in accordance with either the HWC system (hot carcass weight) or the EUROP system. Agents often receive bonuses depending on the percentile body weight loss of animals that were, for example, overfed, resulting in tissue constriction and, thus, an increase in the carcass yield. For direct sales this bonus should go to the cattle breeders. Objective methods, for example, USG ultrasound, are used in order to minimize unfair settlements and precisely calculate the quality of a carcass based on measurements performed on live animals (Pogorzelska et al. 1998).

The aims of the research was to indicate the dependencies between a live assessment and selected post-slaughter indicators, for an objective carcass assessment; and to determine the possibilities of forecasting the carcass' quality, for example, by determining the volume of a quarter carcass, or hot carcass weight (HCW) based on live measurements.

MATERIAL AND METHODS

All cows were handled in accordance with the regulations of the Polish Council on Animal Care; and the Warsaw University of Life Sciences (WULS) Care Committee reviewed and approved the experiment and all the procedures carried out in the study.

The animals used in the experiment comprised a total of 128 purebred Holstein Friesian bulls along with 170 crossbred with other beef breeds up to 2 years old. The cross bred bulls were the progeny of 5 different sire breeds (Limousin, Charolais, Belgium Blue and Simmental breeds sires) crossed with Holstein Friesian females. The bulls were raised at certified livestock farms as part of the Quality Meat Program (QMP). All farms were certified by one of the units: EKOGWARANCJA PTRE sp. z o.o., BiocertMałopolska Sp. z o.o., COBICO Sp. z o.o.

All animals underwent a live assessment in which zoometric measurements were performed with the use of a zoometric stick, compass, and measuring tape: body length (BL) the distance between the tail base and the highest point of the withers, rump length (RL) distance between the outer edge of the hip bone and the end of the pin bone, chest girth (CG) as measured just behind the shoulders, hip width (WH) distance between the outer edges of the hip bones, height at withers (HW) the distance measured from the ground to the highest point of the withers, height at the sacrum (HC) height measured at an imaginary line drawn between the hip bones.

The test also included the bulls'final body weight. All measurements were performed directly before slaughter. Then an analysis was performed of the beef carcasses, which had been cooled for 1 h to a temperature of 4°C, to obtain results from an objective assessment of the carcasses that were included in a commercial slaughter line, using computer data analysis to make the assessment. The analysis was conducted based on 2D and 3D photographs taken of the quarters, with a computer. All animals were slaughtered in the same slaughterhouse and assessed by the same device and the same operator (System VBS 2000, E + V, Germany).

The analysis included: classifying the carcass in regard to the EUROP system performed by device VBS 2000, hot carcass weight (*HCW*), i.e., the weight after slaughter; carcass length (*CL*), distance from the first thoracic vertebra to pubic symphysis; carcass width (*CW*), measured at the widest point of the chest, i.e., at the level of the fifth rib; volume whole half-carcass (*VCH*), as the total volume of the right and left half-carcasses; back volume (*VL*), volume of the half-carcasses from the first thoracic vertebra to pubic symphysis; hind quarter volume (*HV*) volume of the back of the half-carcass, cutting between 10th and 11th ribs; forequarter volume (*FV*) volume of the front part of the half-carcass, cutting between 10th and 11th ribs. All these parameters were measured and determined by the VBS 2000 program.

Additionally, the dressing percentage was taken into consideration, which is the ratio of carcass weight to livestock body weight, expressed as a percentage (*BW*).

In order to standardize the measurements, the following indexes were used: live measurements/*BW* expressed in mm/kg, and post-slaughter measurements/*HCW* expressed in mm/kg. All the traits used in tables were expressed as standardized traits, expressed as ratios of *HCW* (*CL*, *CW*, *VCH*, *VL*, *HV* and *FV*) or *BW* (*BL*, *RL*, *CG*, *WH*, *HW*, *HC*).

Statistical analyses were carried out using correlation coefficients and a stepwise multiple linear regression with standardized variables. Standardization of variables was conducted to avoid effect of different units of variables and different range of values. Standardization of variables was conducted by calculating *Z*-score:

$$Z = (x - m)/SD$$

where:
x – value before standardization;
m – mean of variable;
SD – standard deviation of variable.

Such standardization allow to compare regression coefficient between different variables and do not change the strength of relationships between the variables in the analysis of regression. Independent variables that had a significant effect ($P < 0.05$) on the dependent variable were selected in the final regression linear models. The analyses were performed using Statistica 12 software.

RESULTS AND DISCUSSION

Crossbreeding produces heterosis effects with reference to growth. For crossbreed bulls, all live measurements were significantly correlated ($P < 0.05$) with the post-slaughter values (Table 1). Whereas, for the pure breed HF bulls all measurements were significantly correlated ($P < 0.05$) with post mortem traits, apart from, the back volume (*VL*), the forequarter volume of the width of the hips, and muscling. The muscling in dairy

TABLE 1. Pearson correlation coefficients between zoometric measurements and the results of objective post-mortem evaluations of HF bulls and beef breed crosses

	BL		*RL*		*CG*		*WH*		*HW*		*HC*	
	HF	M	HF	M	HF	M	HF	M	HF	M	HF	M
CL	0.735	0.844	0.736	0.829	0.678	0.857	0.686	0.752	0.730	0.897	0.736	0.890
CW	0.745	0.835	0.750	0.815	0.691	0.852	0.708	0.735	0.751	0.889	0.754	0.884
VCH	0.296	0.416	0.287	0.389	0.267	0.392	0.255	0.338	0.294	0.413	0.309	0.416
VL	0.249	0.180	0.193	0.182	0.204	0.170	0.152	0.125	0.206	0.177	0.237	0.18
HV	0.318	0.531	0.351	0.477	0.300	0.510	0.331	0.484	0.344	0.553	0.348	0.557
FV	0.229	0.283	0.203	0.274	0.200	0.263	0.172	0.205	0.214	0.270	0.231	0.271
Fatness	–0.377	–0.490	–0.309	–0.485	–0.285	–0.549	–0.246	–0.507	–0.349	–0.544	0.346	–0.540
Dressing percentage	–0.300	–0.399	–0.262	–0.375	–0.203	–0.363	–0.272	–0.368	–0.262	–0.434	–0.252	–0.426
Conformation	0.097	0.400	0.150	0.337	0.097	0.351	0.070	0.316	0.183	0.436	0.175	0.429

HF – Holstein Friesian bulls; M – beef breed crosses; *BW* – body weight; *BL* – body length; *RL* – rump length; *CG* – chest girth; *WH* – hip width; *HW* – height at withers; *HC* – height at sacrum; *HCW* – hot carcass weight; *CL* – carcass length; *CW* – carcass width; *VCH* – volume whole half-carcass; *VL* – back volume to length heel shoulder; *HV* – hind quarter volume; *FV* – forequarter volume.

bulls in the EUROP system was significantly correlated ($P < 0.05$) only in terms of the height at the withers and hip height measurements. When compared to beef breeds, dairy breeds and dairy-beef crossbreeds are associated with lower dressing-out percentages and less carcass fat. Pfuhl et al. (2007) demonstrated that Holstein bulls were characterized by greater share of subcutaneous, intramuscular, and visceral fat during growth, which reflects the ability of the Holstein, as a dairy breed, to deposit fat as an energy source for milk production, and also points out the capability of Charolaise to extended protein accretion. With dairy bulls, negative correlations appeared for fattening in the EUROP system, and slaughter yield for all live measured characteristics, but in the case of crossbreed beef bulls these dependencies were much more significant.

Excessive fattening, thus increasing body weight, does not correlate with a high slaughter yield and meat quality (Alam et al. 2013). Additionally, Zaujec et al. (2009) reported a positive relationship between dressing percentage and carcass weight in Holsteins. Negative correlations between such characteristics as height at the withers, hip height, and ischium points' width; indicate that taller animals, and bulls with narrower rumps, possess worse muscling and thus produce a worse slaughter yield. Whereas, higher correlations of the chest girth for the objective post-slaughter measurements of crossbreed bulls indicate a higher muscling in these animals and a higher slaughter yield than in the case of dairy bulls.

The strongest correlations between all the measurements occurred for *CL* and *CW*: $r = 0.6–0.75$ for dairy bulls; and $r = 0.72–0.9$ for crossbreed bulls, which may positively indicate the precision of their calibre (Węglarz et al. 2013). Likewise, Lee et al. (2000) reported, that the choice of covariate (back-fat thickness, age, slaughter weight) for the model seems to be important for carcass traits.

The highest correlations for such characteristics as body weight, primal cuts' weight, and meat weight within primal cuts, are indicated by computer measurements of the body and leg outline areas, shoulder width, and the diagonal body length – producing correlations from 0.62 to 0.79 (Sakowski 2006). Similar results were achieved by other researchers (Nogalski 2002). According to Sakowski (2006), in comparison to dairy bulls, crossbreed beef bulls are characterized by a higher weight of primal cuts and meat content, as well as a larger leg outline area. Crossbreed beef bulls produced more correlated values for live measurements, for all body volumes except the back volume *(VL*).

The coefficients of determination (R^2) concerning most of the selected carcass characteristics were higher for crossbreed bulls than for dairy bulls (Tables 2 and 3) – even as much as circa 22% in the case of carcass length (*CL*), and 21% for the hind quarter volume (*HV*). Bozkurt et al. (2017) reported that higher R^2 values were obtained from digital carcass length and digital carcass depth ($R^2 = 76\%$).

Crossbred beef bulls are characterized by a more massive and muscular body in comparison to dairy bulls, which have a lighter build with less muscle. Bozkurt et al. (2017) observed that a 1 cm change in digital carcass length and digital

TABLE 2. Results of stepwise multiple linear regression for HF bulls, coefficients of determination (R^2),standard errors of the estimate (*SE*), and standardized regression coefficients (ß)

		Dependent variables								
		CL	*CW*	*VCH*	*VL*	*HV*	*FV*	Fatness	Dressing percentage	Conformation
R^2		0.586	0.623	0.095	0.087	0.120	0.053	0.142	0.092	0.073
SE		0.564	0.552	0.889	0.939	0.868	0.940	0.981	1.177	0.807
ß	*BL*	0.339	0.362					–0.377	–0.303	
	RL									
	CG		–0.289							–0.537
	WM	0.212	0.282							
	HW		0.468		–1.248					0.682
	HC	0.258		0.308	1.458	0.347	0.230			

HF – Holstein Friesian bulls; M – beef breed crosses; *BW* – body weight; *BL* – body length; *RL* – rump length; *CG* – chest girth; *WH* – hip width; *HW* – height at withers; *HC* – height at sacrum; *HCW* – – hot carcass weight; *CL* – carcass length; *CW* – carcass width; *VCH* – volume whole half-carcass; *VL* – back volume to length heel shoulder; *HV* – hind quarter volume; *FV* – forequarter volume; Dependent variables – features measured post-mortem, standardized for *HCW*; Independent variables – features measured in life, standardized for *BW*.

TABLE 3. Results of stepwise multiple linear regression for beef breed crosses, coefficients of determination (R^2), standard errors of the estimate (*SE*), and standardized regression coefficients (*ß*)

		Dependent variables								
		CL	*CW*	*VCH*	*VL*	*HV*	*FV*	Fatness	Dressing percentage	Conformation
R^2		0.805	0.787	0.168	0.034	0.330	0.076	0.324	0.211	0.228
SE		0.449	0.464	0.938	1.009	0.863	0.982	0.759	0.496	0.772
ß	*BL*						0.277			
	RL				0.185	–0.417		0.362		
	CG								0.455	–0.601
	WM	0.105				0.250		–0.347		
	HW	0.811	0.887					–0.596	–0.867	1.006
	HC			0.410		0.735				

HF– Holstein Friesian bulls; M – beef breed crosses; *BW* – body weight; *BL* – body length; *RL* – rump length; *CG* – chest girth; *WH* – hip width; *HW* – height at withers; *HC* – height at sacrum; *HCW* – hot carcass weight; *CL* – carcass length; *CW* – carcass width; *VCH* – volume whole half-carcass; *VL* – back volume to length heel shoulder; *HV* – hind quarter volume; *FV* – forequarter volume; Dependent variables – features measured post-mortem, standardized for *HCW*; Indivisible variables – features measured in life, standardized for *BW*.

carcass depth causeda 2.4 and 0.35 kg change in carcass weight, respectively.

Only the R^2 of the back volume (*VL*) was lower in the crossbreed bulls group at 5.3%. The remaining R^2 volume values for specific carcass parts (*VCH*, *HV*, *FV*) were higher than in the case of pure breed HF, and thus translated into higher R^2 values for the remaining characteristics; especially conformation and fattening in the EUROP system, which constitutes the basis for cattle suppliers'settlements (Litwińczuk and Grodzki 2014). In the crossbreed bulls'group the highest R^2 values were observed for *CL* and *CV*: 80.5% and 78.7% respectively, which indicates the greatest effect of live measurements on these post-slaughter measurements.

The standardized regression coefficient, that is, the Beta coefficient (ß), for the height at the withers (*HW*) was –1.25 for pure breed bulls, whereas the height at the sacrum (*HC*) was 1.46 for *VL*. As the animal's calibre and height at the withers increased, the carcass length between the heel and shoulder decreased, while *VL* increased as did the hip height. The Beta coefficient (ß) for crossbreed beef bulls for the volume of a whole carcass half (*VCH*) and the hind quarter volume (*HV*), was 0.41 and 0.735 respectively. A higher hip height had an impact on increasing the hind quarter volume and thus the total body volume, which is related to a higher muscle content in the rear body parts of crossbreed bulls, than pure breed bulls. Gama et al. (2013) demonstrated that the heterosis effect is shaped by both environment and production systems. Willington et al. (2018) reported, that the pure Goudali breed has a much lower *in vivo* and slaughter performance than when they are crossed with the Italian Simmental breed. Furthermore, Theunissen et al. (2014) observed a heterosis effect of +0.8% on meat yield for *Bos taurus* crossed with *Bos indicus* breeds.

In both research groups, an increase of the height at the withers resulted in a body conformation of 0.68 and 1.006 for pure breed and crossbreed bulls, respectively. The differences between the groups consisted of body fattening (ß) – –0.60 and slaughter yield (ß) –0.87, along with an increase in the HW in the crossbreed bulls' group with a simultaneous increase of body conformation at 1.006. A lower fat content has a positive impact on the quality of beef carcasses, with a higher conformation in beef breeds and trade crossbreed beef breeds (Pogorzelska-Przybyłek et al. 2014, Nogalski et al. 2018).

CONCLUSION

Live cattle measurements – especially measurements performed on crossbreed beef bulls – may forecast selected characteristics in beef carcasses and classification in the EUROP system; whereas the live measurements performed on the Holstein Friesian breed constituted a weaker indicator of the analysed post-slaughter characteristics than those performed on crossbreed bulls. In taking advantage of an automated beef carcasses assessment, the predicted results concerning the quality of beef carcasses based on live measurements are fully objective. The analysed parameters may constitute a valuable tool in the process of predicting post-slaughter characteristics using the live assessment of young slaughter cattle, and also constitute valuable information in terms of breading, and not only restricted to crossbreeding.

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Streszczenie: *Związek pomiędzy przyżyciową oceną buhajów holsztyńsko-fryzyjskich i mieszańców z rasami mięsnymi a poubojową obiektywną oceną tusz wołowych.* Metody oceny przyżyciowej bydła i poubojowej tusz wołowych są wspólnym i nieodłącznym elementem pracy hodowlanej, ale powszechnie stosowane metody oceny wizualnej nie są w pełni obiektywne. Obecnie coraz częściej stosowane są innowacyjne metody komputerowej analizy obrazu tusz wołowych, charakteryzujące się większą dokładnością. Celem tego badania było ustalenie związku między oceną przyżyciową i poubojową tusz wołowych oraz ustalenie, czy możliwe jest przewidywanie jakości tusz na podstawie przyżyciowych pomiarów. W doświadczeniu użyto byków rasy holsztyn fryzyjskiej (N = 128) oraz mieszańców z rasami mięsnymi (N = 170). Analiza obejmowała pomiary zoometryczne buhajów oraz wyniki obiektywnej oceny tusz przy użyciu komputerowej analizy obrazu. U mieszańców wszystkie pomiary przyżyciowe były istotnie skorelowane (*P* < 0,05) z wynikami poubojowymi. Współczynniki determinacji (R^2) były wyższe u mieszańców niż u byków mlecznych o ponad 20% w przypadku odległości między stawem skokowym a barkowym i dla objętości tylnej ćwiartki. W obu grupach doświadczalnych większe wartości w kłębie towarzyszyły wyższym konformacjom tusz (standaryzowane współczynniki regresji – *ß*) 0,68 i 1,006, odpowiednio dla czystorasowych byków i mieszańców. Przyżyciowe pomiary bydła – w szczególności pomiary przeprowadzone na mieszańcach z rasami mięsnymi, mogą prognozować wybrane cechy tusz wołowych.

Słowa kluczowe: tusza wołowa, buhaj, mieszaniec ras mięsnych, obiektywna ocena, przyżyciowe pomiary

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