Use of computer image analysis for *in vivo* estimates of the carcass quality of bulls

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ABSTRACT: The aims of the paper were to construct models for the estimation of carcass quality by means of computer image analysis and to verify computer photometry as an *in vivo* method of carcass quality prediction. Results of photometric measurements and carcass quality of 118 Slovak Pied bulls slaughtered at the age of 15 to 18 months were analysed. Nine length dimensions and four area dimensions were measured on the images of the top, left and rear view of each animal. Hot carcass weight (HCW), weight of meat in carcass (WMC) and weight of meat in valuable cuts (WMVC) were obtained after slaughter treatment and carcass dissection. HCW, WMC and WMVC revealed a maximum correlation with the top-view body area (r = 0.54–0.60) and thurl width (r = 0.58–0.60). Stepwise regression was applied to construct linear regression equations for HCW, WMC and WMVC in two alternatives using photometrical dimensions with and without weight before slaughter (WBS). R^2 in an alternative without WBS were lower (R^2 = 0.47–0.55); however R^2 in an alternative with weight before slaughter were higher and highly significant (R^2 = 0.83–0.92). In both alternatives, the equation for HCW had the highest R^2 and the equation for WMVC had the lowest R^2. Equations using photometric dimensions and WBS are suitable to estimate HCW, WMC and WMVC without detailed dissection.

Keywords: cattle; carcass quality; computer image analysis; Slovak Pied breed

The rearing of bulls of dual-purpose breeds – Slovak Pied and Slovak Pinzgau – is a traditional source of high-quality beef production in Slovakia. The Slovak Pied breed derives from the Simmental breed and is reared as a combined milk-meat dual-purpose type. Slovak Pied bulls have excellent fattening characteristics and good carcass. Fattening bulls are mostly marketed alive, which often handicaps breeders. The objectivity of purchase was improved by introducing the EUROP system of carcass quality evaluation. However, since an assessment is carried out by one (though trained) person, the method is subjective and the impartiality of the value is not guaranteed. Marketing can be more objective by using instruments for assessing the carcass constitution. The evaluation of carcass sides in pigs is carried out by different instruments based on the ultrasound principles or VIA methods (Video Image Analysis). Modern computer methods like photometry that use image computer analysis can also be employed. The analysis of relationships between live animal and carcass dimensions measured by software on digitalized images and carcass quality parameters could bring suitable regression equations for *in vivo* or *post mortem* cattle carcass quality assessment.

Photometry is an objective, non-destructive method that has been used by several authors to predict the slaughter value of cattle, pigs and sheep. Photometry was described for the first time by Leydolph in 1954 (cited by Simm 1983). Simm mentioned Weninger (1966), who worked on the application of photometry in predicting the slaughter value of animals, as the next generation of scientists after Leydolph. Misztal (1975) pioneered the method proving that the values of determination coefficient R^2 = 0.86–0.91 were applicable to predict slaughter value *in vivo*. Jankowski et al. (1978) calculated the correlation coefficients between stereophotometric dimensions of different body parts and the slaughter value to range between r = 0.20 and 0.71 and, using identical indices, he recorded model determination coefficients R^2 = 0.48–0.94. In Poland, Sakowski and Cytowski (1996) used a computer analysis of live animal images to estimate the cold carcass weight of Polish Black and White and Piedmont cattle. The results obtained by Sakowski et al. (1996) pointed at a rather high correlation between photometric dimensions and slaughter characteristics. Model determination coefficients in which photometric indices had been included revealed the values 0.96 for cold carcasses and 0.94 for valuable cuts.

This paper was aimed at the construction of suitable models of slaughter value estimation by means of computer image analysis. The other goal was to verify computer photometry as an *in vivo* method of carcass quality prediction in fattening bulls of the Slovak Pied breed.

MATERIAL AND METHODS

The results of photometric measurements of 118 Slovak Pied bulls were analysed. The animals were slaughtered at the age of 15 to 18 months, having reached the average age of 454 days and average live weight of 493.1 kg.

The equipment consisted of a digital Canon Still Video Camera ION RC-260, personal computer with SVGA, frame grabber and original RULER SAI software (Sakowski and Cytowski, 1996).

Images of the top, left and rear view and body dimensions of each animal were taken 5–8 days before slaughter and processed by the Photo Styler software (U-Lead Systems, Inc.) by cutting the unnecessary part and modifying the contrast between the animal and the environment in order to improve the identification of the site. Photometry itself was carried out in the RULER SAI software. Nine length dimensions (height at withers, height at rump, diagonal length of trunk, straight length of trunk, length of thigh, length of shoulder blade, width of shoulder, thurl width and pin width) and four area dimensions (left-view body area, left-view thigh area, top-view body area and rear-view thigh area) were obtained. Height at withers, height at rump, thurl width and oblique length of trunk were measured on the live animals to found out correlation coefficients between them and similar photometric dimensions. The animals were slaughtered at an experimental slaughterhouse of the Research Institute of Animal Production in Nitra. Hot carcass weight (HCW) was determined immediately after slaughter treatment of each carcass. After 24 hours of chilling the right carcass sides were fabricated into retail products by technological dissection. Weight of meat in carcass (WMC) was calculated as total meat cut (boneless) from the right carcass side multiplied by two. Of the wholesale cuts, the weight of meat in valuable cuts (WMVC) was determined as the sum of boneless round, shoulder, loin end and tenderloin multiplied by two. Data obtained in this way were used in statistical analysis. Dressing percentage (DP), proportion of meat in carcass (PMC), proportion of meat in valuable cuts from the weight of hot carcass (PMVC_CW) and proportion of meat in valuable cuts from total meat weight (PMVC_TM) were calculated based on the results of dissection.

Analysis was carried out with the statistical program package SAS 8.02 using the STAT and REG (SAS, 2001). The basic statistics (arithmetic mean, maximum, minimum and standard deviation) were calculated for photometrical measures, body dimensions and carcass quality parameters. Next to that, Pearson's coefficients of linear correlation were calculated between carcass quality parameters, weight before slaughter and photometric dimensions.

In order to construct the most suitable model of estimating selected carcass quality parameters the stepwise procedure was used. All 13 photometrical body dimensions entered the procedure. Based on the results of several authors (Jensen et al., 1985; Henningsson et al., 1986) and our preliminary studies (Polák et al., 2001; Polák, 2005) a high impact of weight before slaughter on carcass quality parameters was expected. Therefore two alternatives of linear regression equations for the estimation of carcass quality parameters were studied – with (A alternative) and without weight before slaughter (B alternative).

General form of the equations

Alternative A – with weight before slaughter

$y_i = a + b_1x_{1i} + b_2x_{2i} + b_3x_{3i} + b_4x_{4i} + b_5x_{5i} + e_i$

Alternative B – without weight before slaughter

$y_i = a + b_2x_{2i} + b_3x_{3i} + b_4x_{4i} + b_5x_{5i} + e_i$

where:

y_i = individual observation of HCV, WMC and WMVC (i = 1, … , 118)

a = intercept

b_1 = partial linear regression coefficients of the dependence of carcass quality parameters (HCV, WMC and WMVC) on weight before slaughter (i = 1, … , 118)

b_2, b_3, b_4, b_5 = partial linear regression coefficients of the dependence of carcass quality parameters (HCV, WMC and WMVC) on photometrical dimensions selected by the stepwise procedure (i = 1, … , 118)

x_{1i} = weight before slaughter (i = 1, ..., 118)

$x_{2i}, x_{3i}, x_{4i}, x_5$ = photometrical dimensions selected by the stepwise procedure

e_i = random errors, N(0,σe2) (i = 1, ..., 118)

The use of higher-degree polynomials for the prediction of WMC and WMVC was also studied but they did not significantly improve the predictability of the model.

RESULTS AND DISCUSSION

The basic statistical values (arithmetic mean, standard deviation) of the slaughter characteristics, photometrically determined body dimensions and body dimensions measured on live animals are shown in Tables 1–3. The average lifetime daily gain of the group was 1 020 g and average daily gain between 150th and 450th day was 1 250 g. Dres-

Table 1. Basic statistics of slaughter value parameters

Variable	Mean	SD
Weight before slaughter (kg)	493.1	21.21
Average lifetime daily gain (g)	1 020.5	90.58
Average daily gain in test (g)	1 250.1	129.53
Hot carcass weight (kg)	280.9	30.35
Weight of meat in carcass (kg)	200.8	23.23
Weight of meat in valuable cuts in carcass (kg)	111.4	13.67
Dressing percentage (%)	507.9	50.3
Proportion of meat in carcass (%)	56.0	1.8
Proportion of valuable cuts in carcass (%)	35.8	1.6
Proportion of valuable cuts in total meat (%)	19.8	0.9

Table 2. Basic statistics of body dimensions obtained by image digitalization

Variable	Mean	SD
Height at withers (cm)	125.5	5.09
Height at rump (cm)	130.7	4.97
Length of trunk (cm)	116.3	7.04
Diagonal length of trunk (cm)	151.9	7.94
Thurl width (cm)	55.4	3.14
Pin width (cm)	19.42	1.82
Shoulder width (cm)	53.7	3.39
Length of thigh (cm)	123.4	5.34
Length of shoulder blade (cm)	45.5	4.68
Left-view thigh area (cm^2)	3 009.1	300.01
Left-view body area (cm^2)	10 780.0	902.89
Top-view body area (cm^2)	7 591.2	666.26
Rear-view thigh area (cm^2)	1 758.1	231.42

Table 3. Basic statistics of body dimensions measured on live animals

Variable	Mean	SD
Height at withers (cm)	127.8	4.04
Height at rump (cm)	135.1	4.19
Diagonal length of trunk (cm)	147.7	5.79
Thurl width (cm)	45.3	1.78

$P < 0.05$; $^{**}P < 0.01$

sing percentage was 56.04%, proportion of meat in carcass was 71.71% and proportion of valuable cuts in total meat was 55.46%.

The absolutely highest correlation coefficients were found between absolute carcass quality parameters (expressed by weight) and weight before slaughter (r = 0.90 in WMVC, r = 0.91 in WMC and r = 0.96 in WHC) but very low correlation coefficients were found between relative carcass quality parameters (r = 0.09 in DP, r = 0.08 in PMC, 0.16 in PMVC_CW and 0.11 in PMVC_TM). The highest correlation coefficients between photometrical body dimensions and carcass quality parameters were calculated for shoulder width (r = 0.53–0.59), thurl width (r = 0.58–0.60), top-view body area (r = 0.38–0.47) and left-view body area (r = 0.54–0.60). The remaining correlations between absolute carcass quality parameters were statistically significant except for the length of shoulder blade. When the proportional characteristics of carcass quality were correlated with photometrical body dimensions, coefficients of correlations were low or negative low and did not provide any meaningful information about the relationships between relative carcass quality parameters and photometrical body dimensions. All calculated Pearson's coefficients of linear correlation are given in Table 4. Similarly like in Jensen et al. (1985), Henningsson et al. (1986) and in our preliminary papers (Polák et al., 2001; Polák, 2005), the high

Table 4. Pearson's coefficients of linear correlation between carcass quality characteristics and photometric body dimensions

Variable	Hot carcass weight	Weight of meat in carcass	Weight of valuable cuts	Dressing percentage	Proportion of meat in carcass	Proportion of valuable cuts in carcass	Proportion of valuable cuts in total meat
Weight before slaughter	0.96**	0.91**	0.90**	0.09	0.08	0.16	0.11
Height at withers	0.32**	0.26**	0.29**	0.15	–0.02	0.02	0.04
Height at rump	0.30**	0.25**	0.30**	0.10	–0.07	0.07	0.17
Length of trunk	0.32**	0.22**	0.28**	0.07	–0.19	–0.01	0.21*
Diagonal length of trunk	0.40**	0.27**	0.34**	0.06	–0.22*	–0.04	0.22*
Thurl width	0.59**	0.59**	0.53**	0.28*	0.15	0.04	–0.12
Pin width	0.20*	0.19*	0.22**	–0.04	0.03	0.11	0.11
Shoulder width	0.58**	0.60**	0.60**	0.25*	0.19*	0.16	–0.03
Length of thigh	0.33**	0.28**	0.31**	0.05	–0.04	0.05	0.12
Length of shoulder blade	0.11	0.09	0.10	–0.08	–0.01	0.03	0.05
Left-view thigh area	0.40**	0.35**	0.36**	0.15	–0.03	0.02	0.05
Left-view body area	0.47**	0.38**	0.41**	0.05	0.12	0.03	–0.10
Top-view body area	0.60**	0.55**	0.54**	0.12	–0.13	0.01	0.16
Rear-view thigh area	0.33**	0.35**	0.30**	0.18	0.01	0.03	0.02

$^{*}P < 0.05$; $^{**}P < 0.01$

effect of weight before slaughter on carcass quality parameters was proved. The correlations between the image dimensions and the slaughter value indices were in accordance with those observed by Jankowski et al. (1978), who found the correlation coefficients between the stereophotometric dimensions of selected body indices and the slaughter characteristics to range within an interval of $r = 0.20$ and 0.70. These results differed from those reported by Sakowski and Cytowski (1996) and Sakowski et al. (1996). Where these authors found high correlations (rump height $r = 0.67$, diagonal body length $r = 0.71$), we could state them to be low ($r = 0.32$ and 0.40, respectively). Where our correlation coefficient was proved to be high (shoulder width $r = 0.59$), Sakowski found a slightly lower one (0.49). This may be explained by the fact that Sakowski carried out measurements in the Polish Lowland Black and White breed whereas we used the Slovak Pied cattle. The Polish Lowland Black and White breed is aimed at milk production and it is affected by the immigration of Holstein genes. The meat yield of that breed is well expressed by its height and length dimensions. The Slovak Pied breed belongs to the family of Simmentalized breeds with meat yield characterized by the width and depth dimensions as well as by the convex patterns of valuable meat parts. As can be seen from Table 4, the relations of photometric body dimensions with absolute carcass quality characteristics (WMC and WMVC) were much tighter than those between photometric body dimensions and relative carcass quality characteristics (PMC, PMVC_CW and PMVC_TM). The informative value of absolute carcass quality characteristics was higher than the traditionally used relative values expressed in percentage.

Body areas obtained by photometrical methods had significant correlation coefficients for almost all photometrical length dimensions except for pins width. The coefficients of correlation between photometrical dimensions are shown in Table 5. Correlation coefficients were calculated for height at withers, height at rump, thurl width and diagonal length of trunk measured on live animal and on digitalised image as well (Table 6).

The lowest coefficient (0.53) was found for diagonal length of trunk and the highest for rump height (0.66). All photometric body dimensions are sensitive to the correct position of the animal on the image, quality of digital image and team experience. One of the sources of variability can be the quality

Table 5. Pearson's coefficients of linear correlations between photometric body dimensions

Variable	Height at rump	Length of trunk	Diagonal length of trunk	Thurl width	Pin width	Shoulder width	Length of thigh	Length of shoulder blade	Rear-view thigh area	Left-view thigh area	Left-view body area	Top-view body area
Height at withers	0.75**	0.51**	0.70**	0.25	–0.05	0.21**	0.52	0.08	0.24**	0.64**	0.76**	0.27**
Height at rump		0.60**	0.72**	0.17	–0.01	0.20	0.67**	0.21**	0.18*	0.76**	0.73**	0.23*
Length of trunk			0.81**	0.09	0.15	0.15	0.49**	0.32**	0.12	0.56**	0.68**	0.29**
Diagonal length of trunk				0.18*	0.05	0.14	0.62**	0.25**	0.13	0.67**	0.84**	0.35**
Thurl width					0.04	0.70**	0.14	0.20**	0.15	0.31**	0.33**	0.73**
Pin width						0.01	0.14	0.11	0.23**	–0.01	0.04	0.06
Shoulder width							0.19*	0.21**	0.28**	0.30**	0.30**	0.77**
Length of thigh								0.28**	0.21**	0.70**	0.59**	0.25**
Length of shoulder blade									0.12	0.24**	0.17	0.32**
Rear-view thigh area										0.25**	0.17	0.24**
Left-view thigh area											0.73**	0.38**
Left-view body area												0.42**

$^{*}P < 0.05$; $^{**}P < 0.01$

Table 6. Coefficients of linear correlation between dimensions measured on the live animal and those obtained by photometric method (n = 106)

Body dimensions	Coefficient of correlation
Height at withers	0.57**
Height at rump	0.66**
Diagonal length of trunk	0.53**
Thurl width	0.56**

*P < 0.05; **P < 0.01

of scaling during taking a picture and during the process of measurement. From this aspect the measuring operator has to be trained and experienced to adjust the scale properly and to identify points determining certain measures in the image. In spite of the fact written above photometrical measures were comparable with direct body measures and using them in the equations did not produce any logical and mathematical mistakes.

Generally, it can be stated that the correlation coefficients between carcass quality parameters and photometric dimensions revealed different dependences. Maximum correlation coefficients of the individual photometric dimensions were observed with the hot carcass weight mainly followed by the weight of valuable cuts and meat weight in the carcass.

Stepwise regression analysis was used to create linear regression equations for the estimation of three carcass quality parameters (HCW, WMC, WMVC). Exact forms of the constructed linear regression equations for alternative A are in Table 7 and for alternative B in Table 8. The linear regression equations in alternative A had coefficients of determination R^2 = 0.47 – 0.55. R^2 of equations in alternative B were highly significant almost twice higher. In both alternatives the equation for estimation of the weight of hot carcass had the highest R^2 and the equation for estimation of WMVC had the lowest R^2.

The values reported by Sakowski et al. (1996) are similar to the results of our alternative B. Results similar to those published by Sakowski and Cytowski (1996) and Sakowski et al. (1997) were also reported by Misztal (1975) and Jankowski et al. (1978). In comparison with groups evaluated by other authors our group was smaller by number.

In photometry, the results mainly depend on the posture of the animal at the moment of imaging. A living animal becomes nervous in the presence of man and is not always willing to stand in a correct posture. This can lead to inaccuracy when determi-

Table 7. Linear regression equations for carcass quality parameters – alternative A

Dependent variable	Intercept	Linear regression coefficients							R^2
		WBS	SW	DLT	TW	LSB	LWTA	TWBA	
HCW	–36.19	0.54	0.88			–0.28	0.004		0.92
WMC	–24.63	0.21	0.33	–0.29	0.43				0.85
WMVC	–16.43	0.40						–0.001	0.83

HCW – hot carcass weight; WMC – weight of meat in carcass; WMVC – weight of meat in valuable cuts; WBS – weight before slaughter; SW – shoulder width; DLT – diagonal length of trunk; TW – thurl width; LSB – length of shoulder blade; TWBA – top-view body area; TWBA – top-view body area; R^2 – coefficient of model determination

Table 8. Linear regression equations for carcass quality parameters – alternative B

Dependent variable	Intercept	Linear regression coefficients						R^2
		SW	DLT	PW	TW	LSB	RWTA	
HCW	–253.2	2.82	1.18	2.46	2.97	–0.77	0.018	0.55
WMC	–87.32	1.12	0.27	0.91	1.25	–0.29	0.008	0.51
WMVC	–57.47	0.43	0.22	0.76	0.88	–0.15		0.47

HCW – hot carcass weight; WMC – weight of meat in carcass; WMVC – weight of meat in valuable cuts; SW – shoulder width; DLT – diagonal length of trunk; PW – pin width; TW – thurl width; LSB – length of shoulder blade; RWBA – rear-view body area; R^2 – coefficient of model determination ning body dimensions and thus also to less reliable estimates of slaughter value. The operator's experience in taking animal images is crucial and so acts in concert with the team mainly at decreasing the time necessary for *in vivo* imaging.

CONCLUSION

The intermediate and upper intermediate values of correlation coefficients show that photometrical measures were comparable with body measures determined on live animals and that using them in regression equations for the prediction of carcass quality did not produce any logical and mathematical mistakes. The linear regression equations which comprised weight before slaughter had significantly higher coefficients of determination than those without this parameter. In our opinion, models using photometric dimensions and weight before slaughter were suitable to estimate carcass composition without detailed dissection, i.e. they can be used as an objective method in the payment system. The models can also be employed to estimate carcass composition in living animals, breeding animals, i.e. to predict the breeding value of carcass composition. In order to improve the accuracy of the results, the number of animals per group and the range of age and weight categories have to be increased. In this case, the effects of age or weight categories should be eliminated.

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