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The relationship of parameters of body measures and body weight by using digital image analysis in pre-slaughter cattle

Abstract

The objective of this study was to predict body weight (BW) of pre-slaughtering beef cattle using digital image analysis. Data used in this study were collected from slaughterhouses in Isparta and nearby provinces from 140 animals. Selected body measurements such as body weight (BW), wither height (WH), body length (BL), chest depth (CD), hip width (HW), hip height (HH) and body area (BA) of different breeds of beef cattle were combined and compared by digital image analysis. The body area was included as a different parameter for prediction of BW instead of chest girth. However, regression equation that included only body area gave the lowest R^2 value for Holstein (18.0%), but the R^2 value was 43.2 and 51.7% for Brown Swiss and crossbred animals, respectively. The regression equation which included all body traits resulted in R^2 values 35.3, 85.1, and 79.6% for Holstein, Brown Swiss and crossbred, respectively. The regression equation which included body area and body length showed that prediction ability of digital image analysis was high for prediction of BW in Brown Swiss and crossbred animals compared to Holsteins (R^2 82.6, 76.5, and 29.5%, respectively). Results indicated that the prediction ability of digital image analysis was low for prediction of BW. Although possibility of using body area as a parameter in predicting BW is low it can be developed by further and better designed experiments.

Key Words**:** slaughtering bulls**,** body weight, body traits, cattle, digital image analysis

Zusammenfassung

Titel der Arbeit: **Beziehungen von Körpermaßen und Messwerten der digitalen Bildanalyse vor der Schlachtung zum Körpergewicht bei Schlachtrindern**

Ziel war die Prüfung einer Vorhersage des Körpergewichtes von Rindern mittels der digitalen Bildanalyse sowie verschiedener Körpermaße. In die Untersuchung waren 56 Holstein Friesian-, 30 Brown Swiss- und 54 Kreuzungsbullen aus Schlachthöfen der Isparta-Provinz einbezogen. Neben dem Körpergewicht wurden die Körpermaße Widerristhöhe, Körperlänge, Hüfthöhe und –breite, Brustumfang und Körperfläche bestimmt. Die einzelnen Messwerte wurden in Beziehung zu den Ergebnissen der digitalen Bildanalyse gesetzt. Die niedrigsten Regressionswerte (R^2) fanden sich bei Holstein Friesianbullen mit 18 % während die Werte für Swiss Brown und Kreuzungsbullen bei 43,2 bzw. 51,7 % lagen. Die R^2 Werte welche alle Körpermaße einschlossen betrugen in der genannten Reihenfolge der genetischen Gruppen 35,3, 85,1 bzw. 79,6 %. R^2 Werte welche Körperfläche und Körperlänge einbezogen ergaben für die Brown Swiss und Kreuzungsbullen bessere Werte (R^2 = 82,6 bzw. 76,5 %) als für die Holstein Friesian Bullen (R^2 = 29,5 %) Die Ergebnisse zeigten, dass eine Vorhersagemöglichkeit des Körpergewichtes mittels der digitalen Bildanalyse bei der vorliegenden Versuchsanstellung als relativ gering zu beurteilen ist.

Schlüsselworte: Schlachtbullen, Körpergewicht, Körpermaße, digitale Bildanalyse

Introduction

Body weights (BW) represent one of the most important economic traits in beef cattle. BW is also good indicator of animal condition (POLGAR et al., 1997; VAN MARLEKÖSTER et al., 2000). Methods to estimate weight can be important where weighing facilities are unavailable (ULUTAS et al,. 2002). The use of body weight

criteria in ration formulation, drug estimation, body condition score, the decision of the date of the first insemination of heifers and marketing requires sophisticated facilities which are expensive and hardly affordable to many small scale farmers (BOZKURT, 2006; WILLEKE and DÜRSCH, 2002).
Several technologies have evaluated to determine the accuracy and precision for predicting body composition. In this purpose, the ultrasound technology began for determine body composition in 1950s (RÖSLER, ZALESKY and BEAL, 2005). McDONALD and CHEN (1990) used digital image analysis technology regarding meat quality investigation in beef cattle that described differences in reflection between meat and fat in *Musculus longissimus dorsi* (MLD). GERRARD et al., (1996) studied description of colour and degree of marbling on beef. LI et al., (1997) showed that brittleness of meat could be determined by vision texture analysis. Similarly, investigations have shown this method can be used to analyze meat, determine marbling score and evaluate MLD area (NEWMAN, 1984; KUCHIDA et al., 1991; SHACKELFORD et al., 1998; SHIRANITA et al., 2000; KARNUAH et al., 2001; CANNELL et al., 2002; TEIRA et al., 2003). BOZKURT et al., (2006) used digital image analysis technology regarding prediction of body weight from body measurements in beef cattle. Therefore, the objective of this study was to examine prediction of body weight from body measurements and body area (BA) of pre slaughtering beef cattle using digital image analysis. Body measurements obtained by digital image analysis system included body area as a different parameter for prediction of body weight as well as body length, wither height, hip width, hip height and chest depth.

Materials and methods

Animal

The animals used in this study included 140 cattle, 56 Holstein, 30 Brown Swiss and 54 crossbred steers. Animals were selected from commercial slaughterhouses in Isparta and nearby provinces. Animals were weighed using a mobile scale before slaughter (Marmara0580 MEB). All procedures were applied by the Institutional Animal care and use committee.

Body Measurements

Body measurements were taken while animals were standing in a squeeze chute after weighing. Body traits were measured by measuring stick except chest girth, which was measured by measure tape.
Wither Height (WH) – was distance from the ground beneath the animal to the top of the withers directly above the centre of shoulder,
Body Length (BL) – was the distance from point of shoulders to the ischium; in other words, from sternum (manubrium) to the aitchbone (tiber ischiadicum),
Hip Width (HW) – was the widest point at the centre of stifle,
Hip Height (HH) – was distance from the ground beneath the animal to the top of the hips directly above the centre of hip,
Chest Depth (CD) – from sternum area immediately caudal to the forelimbs to top of the thoracic vertebra,
Chest Girth (CG) – was measured as the minimal circumference around the body immediately behind the front shoulder,

Body Area (BA) – was measure the area covered by animal in digital photo.

The video recording took place outside the slaughterhouse immediately after weighing while animals were standing in a squeeze chute. The video camera (Canon MV850i) was situated of the level of the animals. At the beginning of the analysis of digital images, calibration was conducted using reference card (1x15 cm). Digital images were downloaded from the camera to a computer file and processed using Image Pro Plus5 software to obtained body measurements from the image in cm.

Statistical Procedure

The best prediction equations for body weight from other body traits, including WH, BL, HW, HH, CD and BA, were determined. Descriptive statistics and regression analysis of body weight (BW) on each of the independent variables were performed using regression analysis procedure of MINITAB, 13 Inc. (Version 13, State Collage, PA, USA 2001).

Regressions of body weight on WH, BL, HW, CD and CG utilizing individual observations were performed. The body measurements obtained by digital image analysis included BA as a different parameter for prediction of BW instead of CG.

Correlation coefficients were also obtained among parameters. Polynomial regression analysis of body weight on WH, BL, HW, HH, CD and BA were performed.

Linear, quadratic and cubic effects of independent variables on BW were included in the following model:

$$Y_i = b_0 + b_1 X_i + b_2 X_i^2 + b_3 X_i^3 + e_i$$

Where Y_i = BW observation of an *i* th animal, b_0 = intercept, b_1, b_2, b_3 = corresponding linear, quadratic and cubic regression coefficients, X_i = independent variables (WH, BL, HW, HH, BD and BA), e_i = residual error term.

Results and discussions

Descriptive statistics of body weight and body traits are shown in Table 1

Regressions of each breed's body weight on various body measurements using digital image analysis are shown Table 2, 3 and 4. Results of each breed's body weight on linear, quadratic and cubic effects of each body measurement are presented in Table 5. Correlation coefficients of traits are shown in Table 6.

Although all R^2 values were found low, the R^2 values from regressions indicated that body area was the lowest related to body weight for Holstein using digital image analysis (Table 2)

Table 1
Descriptive statistic of body weight and body traits **(**Beschreibende Statistik für Körpergewichte und Körpermaße)

Variables	Breeds	N	Mean ± SE
Body Weight (cm)	Brown Swiss	30	440.7^{a} ± 25.7
	Holstein	56	513.4^{b} ± 11.6
	Crossbred	54	460.9^{a} ± 13.6
Body Length (cm)	Brown Swiss	30	136.88^{a}±1.97
	Holstein	56	146.37^{b}±0.95
	Crossbred	54	140.15^{a}±1.26
Wither High (cm)	Brown Swiss	30	123.45^{a}±1.40
	Holstein	56	132,60^{b}± 0.66
	Crossbred	54	127.95^{c}±1.14
Hip High (cm)	Brown Swiss	30	128,87^{a}±1.46
	Holstein	56	137,20^{b}±0.68
	Crossbred	54	132.16^{a}±1.12
Hip Width (cm)	Brown Swiss	30	43,283^{a}±0.87
	Holstein	56	46.152^{b}±0.58
	Crossbred	54	43.222^{a}±0.56
Chest Depth (cm)	Brown Swiss	30	64.78 ^{a}±1.12
	Holstein	56	68.488^{b}±0.75
	Crossbred	54	65.074^{a}±0.68
Chest Girth (cm)	Brown Swiss	30	180.25^{a}±3.38
	Holstein	56	189.36^{b}±1.73
	Crossbred	54	181.59^{a}±.66
Body Area (cm^2)	Brown Swiss	30	14549^{a}± 408
	Holstein	56	16464^{b}± 22
	Crossbred	54	15125^{a}± 298
Body Length (cm)	Brown Swiss	30	139.72^{a}±1.99
	Holstein	56	150.33^{b}±1.06
	Crossbred	54	143.47^{a}±1.34
Wither High (cm)	Brown Swiss	30	126.25^{a}±1.36
	Holstein	56	134.38^{b}±0.68
	Crossbred	54	129.96^{a}±1.21
Hip High (cm)	Brown Swiss	30	130.39^{a}±1.20
	Holstein	56	139.58^{b}±0.78
	Crossbred	54	134.26^{a}±1.19
Hip Width (cm)	Brown Swiss	30	45.284^{a}±0.87
	Holstein	56	47.517^{b}±0.45
	Crossbred	54	45.372^{a}±0.70
Chest Depth (cm)	Brown Swiss	30	68.01^{a}±1.25
	Holstein	56	72.109^{b}±0.71
	Crossbred	54	67.917^{a}±0.82

Table 2
Prediction equations of body weight and linear effects of selected body traits in Holstein cattle by digital image analysis system (Vorhersagegleichungen und lineare Effekte von Körpermaßen und digitaler Bildanalyse bei Holstein Frisian Bullen)

Prediction equations	Constant	BA(cm^2)	BL	WH	HH	HW	CD	R^2%
$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5+b_6x_6$	—469	0.00159	3.27	2.22	-1.68	7.12	0.86	35.3
$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5$	—485	0.00127	3.73	2.23	-1.62	7.20	-	35.2
$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_6x_6$	—531	0.00409	2.96	3.76	-0.50	-	1.32	31.5
$Y=a+b_1x_1+b_2x_2$	—333	0.00640	4.93*	-	-	-	-	29.5
$Y=a+b_1x_1+b_3x_3$	—531	0.00822	-	6.77*	-	-	-	27.0
$Y=a+b_1x_1+b_4x_4$	—257	0.0109	-	-	4.24	-	-	21.7
$Y=a+b_1x_1+b_5x_5$	—119	0.0103	-	-	-	9.74*	-	27.5
$Y=a+b_1x_1+b_6x_6$	—96	0.0127	-	-	-	-	5.55*	26.5
$Y=a+b_1x_1$	153	0.0219*	-	-	-	-	-	18.0
$Y=a+b_2x_2$	—363	-	5.83*	-	-	-	-	28.6
$Y=a+b_3x_3$	—637	-	-	8.56*	-	-	-	25.5
$Y=a+b_4x_4$	—401	-	-	-	6.55*	-	-	19.7
$Y=a+b_5x_5$	—93	-	-	-	-	12.8*	-	24.9
$Y=a+b_6x_6$	—38	-	-	-	-	-	7.64*	22.1

*Statistically significant ($P<0.05$) b is coefficient of variables, X is independent variables (WH, BL, HW, HH, BD and BA)

Inclusion of BL in the equation increased R^2 greatly in every steps of regression for both Brown Swiss and crossbred (Table 3 and 4). The R^2 values of body area with digital image analysis for Brown Swiss and crossbred animals were 43.2 and 51.7, respectively. However the regression equations included both body area and body length showed the highest R^2 for Brown Swiss and crossbred animals (R^2= 82.6 and 79.6, respectively). The equation included all body traits except CD or HW showed the highest R^2 for Brown Swiss (R^2=85.0%). However, the equation that included all body traits except HH was R^2=79.4% for crossbred. The R^2 values which obtained from equation contained BA and BL were found to be 82.6% and 76.5% for Brown Swiss and crossbred respectively. The prediction equation including both BA and BL analyzed by digital image analysis resulted in better prediction than the rest of the equations contained other body traits. The results indicated that BL can be used to predict body weight accurately for Brown Swiss and crossbred cattle (R^2= 80.7% and 75.6%, respectively) (Table 3). These results were higher with findings of BOZKURT (2006) and ULUTAS et al., (2002) who reported that the R^2 values for BL was 70.4% and 68.3%, respectively with traditional method. BOZKURT et al., (2006) reported that R^2 value for BL was 63.6% with digital image analysis. HEINRICHS et al., (1992) and SEKERDEN et al., (1991) indicated that BL can be used to estimate BW from body weight (R^2= 93% and 96.1%, respectively). The relationship between BA and change in body weight is presented in Table 3, 4. The results showed that a 1 cm^2 change in BA resulted in approximately 0.041 and 0.0328 kg change in weigh for Brown Swiss and crossbred cattle, respectively. It was evident that a 1 cm^2 change in BA resulted in lesser weight change compared to the rest of body traits (Table 3 and 4). Similarly, a 1 cm change BL, WH, HH, HW and CD resulted in 11.6, 14.8, 15.3, 22.4 and 17.6 kg change in weight for Brown Swiss and 8.80, 8.97, 9.05, 12.7 and 11.6 kg change for crossbred, respectively.

Table 3
Prediction equations of body weight and linear effects of selected body traits in Brown Swiss cattle by digital image analysis system (Vorhersagegleichungen und lineare Effekte von Körpermaßen und digitaler Bildanalyse bei Brown Swiss Bullen)

Prediction equations	Constant	BA(cm^2)	BL	WH	HH	HW	CD	R^2%
$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5+b_6x_6$	—1866	-0.0266*	12.8*	1.52	5.72	-1.39	0.46	85.1
$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5$	—1880	-0.0267*	13.0*	1.57	5.78	-1.41	-	85.0
$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_6x_6$	—1844	-0.0261*	12.2*	1.67	5.47	-	0.51	85.0
$Y=a+b_1x_1+b_2x_2$	—1315	-0.0150	14.1*	-	-	-	-	82.6
$Y=a+b_1x_1+b_3x_3$	—1286	0.0103	-	12.5*	-	-	-	62.8
$Y=a+b_1x_1+b_4x_4$	—1284	0.0122	-	-	11.9*	-	-	52.5
$Y=a+b_1x_1+b_5x_5$	—572	0.0166	-	-	-	17.0*	-	60.8
$Y=a+b_1x_1+b_6x_6$	—752	0.00072	-	-	-	-	17.4*	72.9
$Y=a+b_1x_1$	—161	0.0414*	-	-	-	-	-	43.2
$Y=a+b_2x_2$	—1181	-	11.6*	-	-	-	-	80.7
$Y=a+b_3x_3$	—1425	-	-	14.8*	-	-	-	61.6
$Y=a+b_4x_4$	—1558	-	-	-	15.3*	-	-	51.3
$Y=a+b_1x_1$	—572	-	-	-	-	22.4*	-	57.1
$Y=a+b_2x_2$	—754	-	-	-	-	-	17.6*	72.9

* Statistically significant (P<0.05) b is coefficient of variables, X is independent variables (WH, BL, HW, HH, BD and BA)

Table 4
Prediction equations of body weight and linear effects of selected body traits in crossbred cattle by digital image analysis system (Vorhersagegleichungen und lineare Effekte von Körpermaßen und digitaler Bildanalyse bei Kreuzungsbullen).

Prediction equations	Constant	BA(cm^2)	BL	WH	HH	HW	CD	R^2%
$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5+b_6x_6$	—767	0.00699	7.85*	2.20	-1.54	3.24	-3.41	79.6
$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5$	—742	0.00662	6.10*	1.66	-1.06	3.38	-	78.6
$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_6x_6$	—787	0.00655	8.81*	2.14	-1.08	-	-3.65	78.0
$Y=a+b_1x_1+b_2x_2$	—743	0.00659	7.70*	-	-	-	-	76.5
$Y=a+b_1x_1+b_3x_3$	—595	0.0134*	-	6.57*	-	-	-	67.8
$Y=a+b_1x_1+b_4x_4$	—626	0.0121*	-	-	6.73*	-	-	66.2
$Y=a+b_1x_1+b_5x_5$	—259	0.0241*	-	-	-	7.85*	-	64.3
$Y=a+b_1x_1+b_6x_6$	—304	0.0203*	-	-	-	-	6.74*	61.0
$Y=a+b_1x_1$	—34.5	0.0328*	-	-	-	-	-	51.7
$Y=a+b_2x_2$	—802	-	8.80*	-	-	-	-	75.6
$Y=a+b_3x_3$	—705	-	-	8.97*	-	-	-	63.7
$Y=a+b_4x_4$	—754	-	-	-	9.05*	-	-	63.3
$Y=a+b_5x_5$	—116	-	-	-	-	12.7*	-	42.7
$Y=a+b_6x_6$	—330	-	-	-	-	-	11.6*	50.0

* Statistically significant ($P<0.05$) b is coefficient of variables, X is independent variables (WH, BL, HW, HH, BD and BA)

Higher order polynomial equations were examined (Table 5). The R^2 values from regressions indicate that BL was highly related to body weight considering all linear, quadratic and cubic coefficient terms for all breeds. The cubic term was non significant ($P>0.05$) for all traits except WH in Brown Swiss (Table 5). HEINRICHS et al., (1992) reported that the cubic term was significant for WH, HW and BL. For all body traits, addition of cubic term increased the R^2 slightly for all breeds (Table 5). All linear terms for all body traits of all breeds were significant ($P< 0.05$).

All correlation values between body weight and body measurements for Holstein, Brown Swiss and crossbred animals were found to be statistically significant ($P< 0.05$). Among all body measurements, high correlation was found between body weight and body length for all breed except Holstein (Table 6). The correlation was found 0.54, 0.89 and 0.87 between body weight and body length in Holstein, Brown Swiss and Crossbred, respectively and this result was in line with findings of BOZKURT (2006) who reported that r= 0.84 in Brown Swiss. TOZSER et al. (2000); CAGLAR and SEKERDEN (1993) and SEKERDEN et al., (1991) represented that correlation coefficient between BW and BL was 0.63, 0.74 and 0.98 respectively. The correlation between BW and BA was found 0.43, 0.66 and 0.72 for Holstein, Brown Swiss and Crossbred, respectively. It was expected that body area would give higher correlation coefficient value than the other body measurements since the R^2 value between body weight and body area was not high.

Table 5
Regressions of body weight on the linear, quadratic and cubic effects of each body measurement# (Regressionen des Körpergewichts auf lineare, quadratische und kubische Effekte bei den einzelnen Merkmalen)

Measurements	**Constant**	**Linear**	**Quadratic**	**Cubic**	**R^2%**
Holstein					
Body Area	153.3	0.02	-	-	18.0
	422.2	-0.01	0.00^{ns}	-	18.2
	-4007.7	-0.82	-0.000^{ns}	0.00^{ns}	19.2
Body Length	-362.7	5.83	-	-	28.6
	-2723.7	36.77	-0.10^{ns}	-	29.8
	-24565.5	466.97	-2.92^{ns}	0.01^{ns}	30.5
Wither High	-636.9	8.56	-	-	25.5
	-3201.2	46.94	-0.14^{ns}	-	25.9
	-66446.1	1475.34	-10.88^{ns}	0.03^{ns}	26.4
Hip High	-401.4	6.55	-	-	19.7
	-4038.5	58.30	-0.18^{ns}	-	20.4
	-38967.6	803.70	-5.48^{ns}	0.01^{ns}	20.5
Hip Width	-93.1	12.76	-	-	24.9
	-1933.7	91.54	0.84^{ns}	-	27.2
	38701.8	-2554.17	56.27^{ns}	-0.41	37.4
Chest Depth	-37.7	7.34	-	-	22.1
	132.5	2.93	0.03^{ns}	-	22.1
	-17444.1	745.92	-10.37^{ns}	0.05^{ns}	25.5
Brown Swiss					
Body Area	-161.0	0.04	-	-	43.2
	1372.5	-0.16	0.00^{ns}	-	48.5
	10833.9	-1.99	0.00^{ns}	-0.00^{ns}	51.3
Body Length	-1180.9	11.61	-	-	80.7
	1918.5	-30.61	0.14^{ns}	-	82.4
	-16191.6	343.27	-2.42^{ns}	0.01^{ns}	82.7
Wither High	-1425.3	14.78	-	-	61.6
	4850.4	-82.11	0.37^{ns}	-	65.2
	127149	-2940.93	22.58^{ns}	-0.06	72.6
Hip High	-1557.8	15.33	-	-	51.3
	8920.8	-142.55	0.59^{ns}	-	55.4
	132897	-2941.55	21.62^{ns}	-0.05^{ns}	57.0
Hip Width	-572.2	22.37	-	-	57.1
	4635.5	-197.49	2.29	-	74.1
	-10763.2	775.16	-18.03	0.14^{ns}	75.6
Chest Depth	-754.1	17.57	-	-	72.9
	2742.6	-79.71	0.67	-	78.0
	-18281.9	808.07	-11.74	0.06^{ns}	79.5
Crossbred					
Body Area	-34.5	0.03	-	-	51.7
	-638.9	0.11	-0.000^{ns}	-	53.9
	1878.8	-0.36	0.000^{ns}	-0.00^{ns}	54.9
Body Length	-802.3	8.80	-	-	75.6
	1145.8	-18.38	0.09^{ns}	-	76.7
	48047.8	-1000.16	6.92^{ns}	-0.02	80.1
Wither High	-704.9	8.97	-	-	63.7
	-727.2	9.31	-0.00^{ns}	-	63.7
	35457.2	-819.74	6.31^{ns}	-0.02^{ns}	65.8
Hip High	-753.7	9.04	-	-	63.3
	-615.9	7.01	0.01^{ns}	-	63.3
	33750.3	-754.96	5.62^{ns}	-0.01^{ns}	64.4
Hip Width	-115.8	12.71	-	-	42.7
	-1534.2	74.08	-0.65	-	51.7
	9177.57	-608.58	13.62	-0.09	65.1
Chest Depth	-329.9	11.64	-	-	50.0
	319.0	-7.35	0.14^{ns}	-	50.4
	10246.1	-452.23	6.73^{ns}	-0.03^{ns}	51.5

Only none significant regression coefficients had superscripts (ns), the rest were significant at $p< 0.05$.

Table 6
Pearson correlations between body weight and selected body traits in breeds (Pearson Korrelationskoeffizienten zwischen Körpergewicht und den einzelnen Messmerkmalen)

Variables	Body Weight Holstein	Brown Swiss	Crossbred
Body Area	0.43	0.66	0.72
Body Length	0.54	0.89	0.87
Wither High	0.51	0.79	0.80
Hip High	0.44	0.72	0.80
Hip Width	0.50	0.76	0.65
Chest Depth	0.47	0.85	0.71

It could be concluded that the digital image analysis can predict the body weight from body traits. When the animals have large frame size such as Holstein prediction of body weight, was lower than prediction obtained in Brown Swiss and Crossbred cattle. However, BA and BL obtained by digital image analysis may be better parameters in predicting weight of Brown Swiss and crossbred cattle.
The digital image analysis is promising approach in predicting body weight of live animals. However, in order to increase accuracy, better controlled conditions should be provided wherein cattle are fixed in squeeze chute. Digital image analysis can be developed to prediction body weight by further and better designed experiments.

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