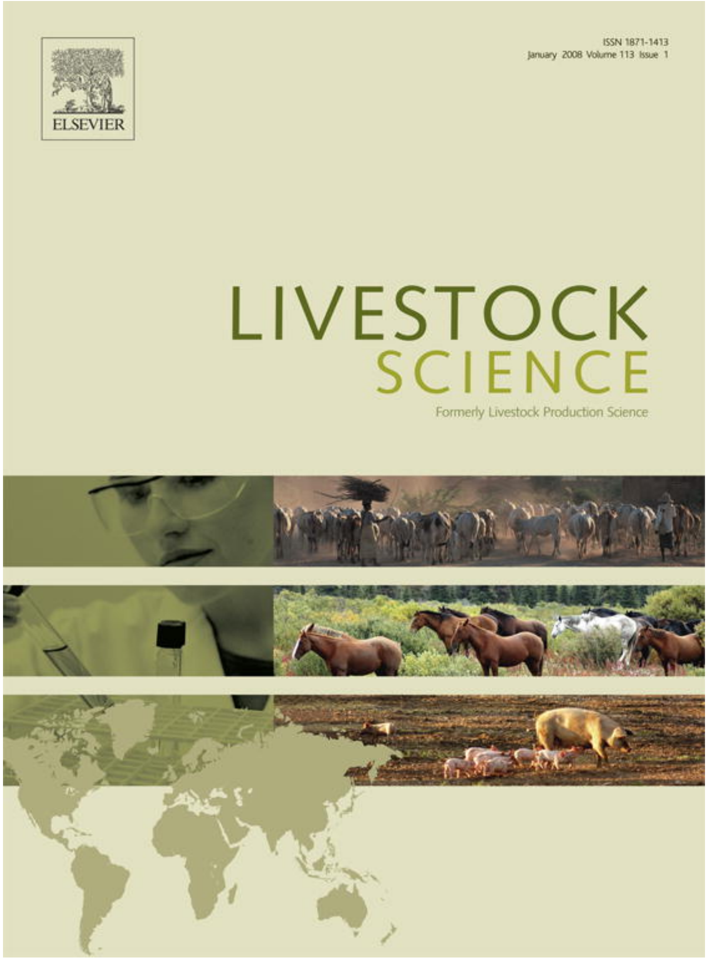
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Review article

Determination of live weight and body condition score in lactating Mediterranean buffalo by Visual Image Analysis

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Abstract

The computerized image analysis system (Visual Image Analysis, VIA) was employed in morphological assays, the determination of live weight (LW) and degree of fattening (body condition score, BCS) of buffalo species. Ten Mediterranean multiparous, lactating buffaloes were selected and measured, both manually (with a Lydtin measuring stick) and by VIA, for the following linear parameters: withers height (WIH), rump height (RUH), body height (BOH), trunk length (TRL) and rump length (RUL). An angular parameter (with the apex at the tip of the rump and with the two half-line tangents at the iliac tuberosities (AIT)) was measured by VIA on 100 Mediterranean multiparous lactating buffaloes, plus three surface parameters, i.e. surface areas of the lateral profile (SLP), of the profile of the hindquarters (SHP) and of the lateral iliac tuberosity (SIT), in addition to recording live weight and BCS. A comparison between linear measurements and VIA showed a large degree of similarity (differences ranged between 0.32 and 1.55%). With respect to the indirect determination of live weight, the simple regression equations (SLP vs. LW; SHP vs. LW) were significant at $P<0.001$ and had high determination coefficients equal to 0.94 and 0.92, respectively. The multiple equation (LW = −427.7445 + 0.0431 SLP + 0.1263 SHP) has an $R^2=0.96$ and significance at $P<0.001$. Satisfactory results ($R^2=0.77$ and 0.81, $P<0.001$) were obtained from the simple regression equations (AIT vs. BCS; SIT vs. BCS) for the objective determination of the degree of fattening; the multiple equation (BCS = −7.4026 + 0.0537 AIT + 0.0180 SIT) was significant at $P<0.001$ with $R^2=0.85$. The results confirm that, for buffalo species, computerized image analysis is an effective measuring system for the indirect determination of live weight. Furthermore, this technique has proved to be technologically innovative for the objective determination of degree of fattening.

Keywords: Visual Image Analysis; Live weight; Body condition score; Mediterranean buffalo

1. Introduction

Historically, there has been considerable awareness of the importance of morphological studies, as can be observed in Publio Virgilio Marone's study "Le Georgiche". However, it was only in the second half of the 18th century that evaluation of species of zootechnical interest began on the basis of the relationship between conformation and productive potential (Bourgelat, 1768; Lecocq, 1840; Goubaux and Barrier, 1884). A number of morphological parameters (linear, angular and perimetric) were identified that were intended to provide, via

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measurement with suitable equipment, useful indicators for morpho-ponderal studies of these species (Tamaro, 1901; Magliano, 1930).

Due to difficulties in weighing large animals in the field, researchers devised barometric methods, based on correlations between some quantifiable morphological parameters and live weight (Sanson, 1886; Mascheroni, 1897; Mastrolilli De Angelis, 1942; Paci, 1947). Among the biometric parameters used for the determination of weight, surface parameters were applied by Roussy (1922) and Elting (1926). Roussy (1922) highlighted the relationship between weight and surface area by placing an "artificial skin" on a horse, which was then removed, laid out flat in pieces and the total surface area calculated by photographic means. Many researchers subsequently sought to improve the precision of these "barimetric" methods (Milner and Hewitt, 1969; Martin Rosset, 1983; Frape, 1986; Martin Rosset and Dubroeucq, 1988; Wolter, 1994; Bergero, 1996), but the measurement of morphologic parameters using traditional zoometry instruments gradually became less suited to modern zootechnics.

To overcome the difficulties connected with biometric examinations, in recent years, studies have involved the use of new measuring instruments, including optical tools based on the analysis of computerized images. Such methodologies present advantages from a technical, economic and ergonomic point of view since they allow morphological measurements to be obtained at a distance (Borggard et al., 1996; Kuchida et al., 1996; Zehender et al., 1996; Barrey et al., 2002; Negretti and Bianconi, 2004).

With regard to weight determination, opto-informatic techniques have been applied for horses (Paragon et al., 2000; Negretti and Bianconi, 2001a), meat cattle (Sakowski and Cytowski, 1996; Negretti and Bianconi, 2001b; Greiner et al., 2003) and pigs (White et al., 2004).

With regard to the determination of the degree of fattening, objective knowledge of the live weight is insufficient. Presently, there are no suitable instruments and there is still reliance on expert assessment, which is limited by the inherent bias of the evaluator. To the best of our knowledge there is no research on the determination of the degree of fattening in species of zootechnical interest using opto-informatic techniques.

In recent years, buffalo species have attracted growing attention, not only in Asian countries, where it is principally found, but also in countries in the Mediterranean basin (Italy, Egypt, Turkey) and in South America (Brazil, Venezuela, Argentina). Consequently, the application of opto-informatic methodologies to this species would be of considerable interest.

Following tests on the reliability of opto-informatic methods, the objective of this study was to verify the potential for indirect determination of live weight and the possibility of objectively determining the degree of fattening in lactating Mediterranean buffalo.

2. Materials and methods

To verify the degree of reliability of the opto-informatic methodology, the following parameters (Fig. 1) were measured using a Lydtin measuring stick on 10 multiparous lactating Mediterranean buffaloes (*Bubalus bubalis* L.): withers height (WIH), rump height (RUH), body height (BOH), trunk length (TRL) and rump length (RUL). For the indirect determination of weight and the

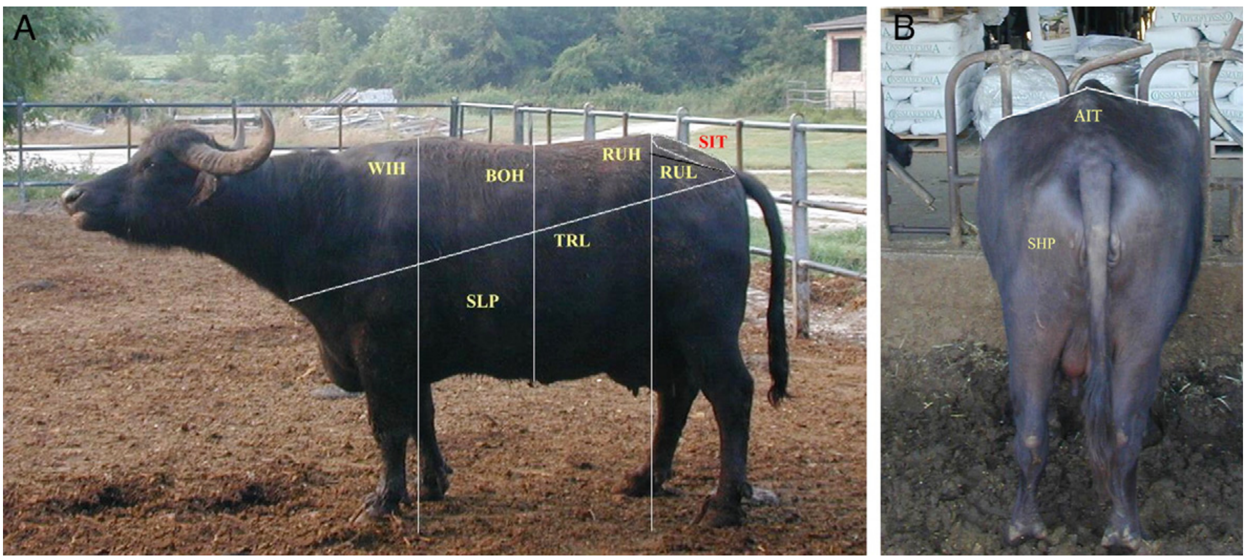

Fig. 1.

Table 1
Evaluation scale of Wagner et al. (1988) for the determination of the degree of fattening, modified for the buffalo species by Campanile et al. (1998)

Score	Description
1	*Severely emaciated.* All ribs and bone structures are easily visible and physically weak. Animal has difficulty in standing and walking. No presence of fat either visible or palpable.
2	*Emaciated.* Similar to point 1 but no weakness present.
3	*Very thin*. No indication of fat either visible or palpable on ribs or brisket. The individual muscles on the hindquarter are easily visible and the spinus processes are very pronounced.
4	*Thin*. Ribs and bony protrusions easily visible with no palpable fat present. Individual muscles still visible on the hindquarters.
5	*Adequate state of nutrition*. The primary ribs appear covered, while the last two or three ribs are clearly visible. The triangle formed by the iliac tuberosity, the ischiatic tuberosity and the coxofemural articulation is clearly visible, and the muscular masses are concave in shape.
6	*Fairly good state of nutrition*. Fat deposits are present at the level of the ribs that are no longer clearly visible. No adipose deposits at the brisket tip. The triangle formed by the iliac tuberosity, the ischiatic tuberosity and the coxofemoral articulation is still clearly visible and the sides formed by the muscular margins are correctly in line. The spiny apophyses of the lumbar vertebrae are still clearly visible. The cross apophyses of the lumbar vertebra is perceptible to finger pressure. No fat at the base of the tail.
7	*Good state of nutrition*. Slight fat deposits at tip of the brisket. The individual ribs are no longer visible. About 1 cm of fat deposit on the bony protrusions and/or on the last two or three ribs. The muscular masses are quite convex in shape. The spiny apophyses and lumbar vertebrae transverses are no longer visible. The base of the tail appears solid.
8	*Fat*. The tip of the brisket appears full and the bony protrusions show fat deposits. The hindquarters look square in shape due to the presence of fat. A demarcation line on the backbone resulting from the presence of fat on each side; at least 1–2 cm of fat on the last two or three ribs. Overall uniform appearance. The demarcation line is very evident on the backbone. Excessive accumulation of fat at the base of the tail; dimple no longer visible.
9	*Very fat*. Hindquarters very square-shaped. The tip of the brisket is very pronounced and stretched by the fat. Heavy fat deposits on the bony protrusions and at the base of the tail. The neck is large, at least 3–4 cm of fat on the last two or three ribs. The demarcation line is very pronounced on the backbone.

objective determination of the degree of fattening, 100 multiparous lactating Mediterranean buffaloes were monitored for live weight (LW) in the morning, prior to feeding, by means of an electronic scale (Perin 440.2000) and estimation of body condition score (BCS) by five experts, utilizing the scale of Wagner et al. (1988), modified for the buffalo species by Campanile et al. (1998). The scale is composed of nine points related to adipose deposits (Table 1).

Simultaneously with the measurements, weight determinations and BCS evaluations, a photographic survey was carried out on each buffalo from lateral and posterior angles. From the lateral photograph (Fig. 1), in addition to the linear parameters previously illustrated, the surface area of the lateral profile of the whole animal (SLP) and the surface area of the iliac tuberosity (SIT), i.e. the surface area between the iliac–ischiatic tuberosity and the outline of the rump, were also measured utilizing the Visual Image Analysis system (VIA). From the photograph of the hindquarters of the animal (Fig. 1), the surface area of the profile of the hindquarters of the entire animal (SHP) and the value of the angle with a peak at the tip of the rump and with the two half-line tangents to the iliac tuberosities (AIT) were measured. The opto-informatic system consisted of a Nikon Coolpiz 800 digital camera with a resolution of more than 2 million pixels, a

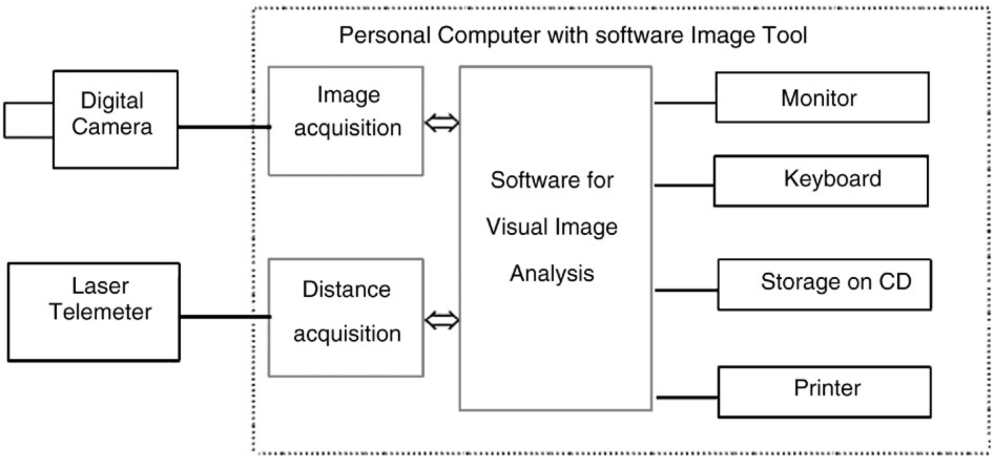

Fig. 2.

Würth WDM-02 laser telemeter to carry out continuous measurements of the distances every 0.5 s, with a measurement field of between 0.3 and 30 m and precision of ±5 mm, and PC compatible image analysis software (Image Tool) to carry out the computerized biometric surveys. Procedures relating to system functionality (Fig. 2) were established according to specific research protocols and validated in previous experiments on bovines reared for milk and for meat (Filippi Balestra et al., 1994; Negretti and Bianconi, 1999). CORR and GLM procedures from the SAS (1993) statistical package were used for data analysis from the morphological surveys to test the reliability of the elaborated methodology. For the indirect determination of LW from SLP and SHP, and for the objective determination of the BCS from AIT and SIT, data derived from 50 animals was used, calculating the regression lines by means of the REG/SAS procedure. Validation was obtained from data of the remaining 50 animals.

3. Results and discussion

3.1. Morphological measurements

Table 2 compares the linear measurements with a Lydtin measuring stick and those undertaken with the VIA system. Differences between the two systems range between 0.32% for withers height and 1.55% for rump length. Correlations are significant ($P<0.01$) and range between 0.91 for body height and rump length and 0.99 for withers height. The levels of significance from variance analysis between the two measuring systems range from 68.46% for rump height to 94.27% for withers height. The high correlations and variance analysis demonstrate the degree of precision and reliability of the opto-informatic measurements compared to the Lydtin stick. The opto-informatic methodology, when applied to the buffalo, could present a problem of applicability due to the dark coat of the animal. Indeed, the colouring could have hampered both the visibility of some points of morphological interest on the video image and the performance of the telemeter laser due to a greater absorption of the signal. The satisfactory result is in agreement with previous studies on dairy cows, where the differences between traditional measurements and VIA technique for various parameters ranged 0.2–2.0% (Negretti and Bianconi, 2004), beef cattle, with differences ranging 1.3–2.2% (Tözsér et al., 2000), sport horses (Barrey et al., 2002), where results were considered "completely satisfactory for conducting reliable statistical analyses".

Table 2
Comparison between the linear measurements undertaken with the Lydtin stick (manual measurement) and those estimated with the Visual Image Analysis system (opto-informatic measurement)

	WIH	RUH	BOH	TRL	RUL
Manual measurement (cm)	134.7±6.7	139.7±4.3	78.5±2.0	156.3±5.5	44.9±2.6
Opto-informatic measurement (cm)	134.9±6.8	138.8±5.4	78.7±2.6	156.5±5.9	44.6±2.5
Difference (%)	0.32	1.09	1.28	0.90	1.55
r	0.99	0.96	0.91	0.96	0.91
Pr>F (%)	94.27	68.46	85.06	93.81	79.40

Table 3
Mean values and data ranges of the live weight (LW), of the surface area of the lateral profile (SLP), of the surface area of the profile of the hindquarters (SHP), used for the regression equations and for their validation

	Mean±s.d.	Range
Regression		
LW (kg)	725.08±104.55	530–1000
SLP (cm^2)	16,157.00±1448.87	14,088–19,948
SHP (cm^2)	3609.00±327.34	3120–4365
Validation		
LW (kg)	722.90±95.99	552–960
SLP (cm^2)	16,032.35±1249.72	14,083–19,086
SHP (cm^2)	3588.35±311.48	3080–4272

3.2. Indirect determination of live weight

For the determination of live weight, the surface area of the lateral profile (SLP) and the surface area of the profile of the hindquarters (SHP) of the buffalo were used. The correlations between weight and surface areas for 100 animals were significant ($P<0.01$) with $r=0.98$ for LW vs. SLP and $r=0.96$ for LW vs. SHP.

Table 3 documents the mean values, standard deviations and range of the three parameters for the 50 animals used to calculate the regression lines and the remaining 50 animals used for validation. The range of parameters employed for validation is included in those used for calculating the regression lines. The variability coefficients of the parameters from the buffaloes utilized for validation are inferior to those used for regression curve determination, demonstrating a suitable choice of animals for a satisfactory validation of the equations.

Table 4 records the regression equations between live weight, SLP and SHP and their validation. The simple regression Eqs. (1) $LW=-407.9851+0.0701$ SLP and (2) $LW=-382.4325+0.3069$ SHP were highly significant ($P<0.001$), with determination coefficients, respectively, of 0.94 and 0.92. Using SLP, similar results were obtained by Negretti and Bianconi (2005a) on beef

Table 4
Regression equations[a] between live weight (Y), surface area of the lateral profile (X_1), surface area of the profile of the hindquarters (X_2)

Regression	a	b_1	b_2	R^2	Rmse
1]	−407.9851	0.0701		0.94***	24.97
2]	−382.4325		0.3069	0.92***	29.35
3]	−427.7445	0.0431	0.1263	0.96***	21.22

Validation	$\text{Weight}_{\text{VIA}}$	Diff_{alg} (kg)	$\%_{\text{alg}}$	Diff_{abs} (kg)	$\%_{\text{abs}}$	<2.5%	2.5–5.0%
1]	716.33±87.64	6.57	0.74	15.83	2.26	56%	44%
2]	718.74±95.58	4.16	0.55	17.27	2.41	56%	44%
3]	717.09±92.47	5.81	0.73	11.97	1.68	72%	28%

Validation of the regression equations.
***$P<0.001$.
[a] $Y=a+b_1*X_1+b_2*X_2$ where X_1=SLP, X_2=SHP.

cattle with $R^2=0.97$ and by White et al. (2004) on pigs with $R^2=0.90$. In the validation procedure, comparing actual weight (722.90 kg) with estimated weight, using Eqs. (1) and (2), gave 716.33 and 718.74 kg, respectively; a difference in absolute value of 2.26% for Eq. (1) and 2.41% for Eq. (2). Considering that individual differences between actual and estimated weight did not exceed 5%, two classes were identified: <2.5% and 2.5–5%. With both equations, a distribution of 56% was obtained in the best class. The multiple regression Eq. (3) LW=−427.7445+0.0431 SLP+0.1263 SHP was also highly significant ($P<0.001$) with $R^2=0.96$, further improving the determination coefficients obtained with the previous equations. Similar results have been reported by Negretti and Bianconi (2005b) for sport horses with $R^2=0.95$. However, no data have been found for other species of zootechnical interest for multiple equations between live weight and surface areas of the profile, either lateral or of the hindquarters. Mean difference, in absolute value, between actual and VIA-estimated weight was only 1.68%; the distribution recorded a further improvement with 72% of the sample being within class <2.5%.

From the equations, it is evident that the surface area of the lateral profile of the buffalo (SLP) is sufficiently precise for indirect determination of weight. Moreover, the additional use of the surface area of the profile of the hindquarters (SHP) leads to a further improvement in accuracy levels, reducing the difference between actual and opto-informatically estimated live weight for individual animals.

3.3. Objective determination of BCS

For the determination of the degree of fattening, the value of the angle with its apex at the tip of the rump and with the two half-line tangents to the iliac tuberosity (AIT) was estimated, which correlated significantly ($P<0.01$) with the total sample, with $r=0.88$ for BCS. In addition, the surface area of the iliac tuberosity (SIT) was also considered, which was significantly correlated ($P<0.01$), with $r=0.89$ to BCS.

Table 5 records the mean values, standard deviations, range of BCS values and the two parameters utilized for the determination of regression curves plus animals used for validation. In this instance, the parameter variability coefficients utilized for validation are also lower than those used to determine the curves. The range of parameters reflected in the validation is included in the regression curve determination range.

Table 6 documents, in addition to their validation, the regression equations between BCS and AIT and SIT. The determination coefficients of the simple regression Eqs. (4) BSC=−9.6426+0.1139 AIT and (5) BSC=−3.7714+0.0295 SIT were equal to 0.77 and 0.81, respectively, which were highly significant ($P<0.001$). Comparing mean BCS data, obtained by five evaluators (6.62 points), with that estimated by Eqs. (4) and (5) (6.62 and 6.61 points, respectively), differences in absolute value of 0.26 points

Table 5
Mean values and data ranges of the body condition score (BCS), of the angle of the iliac tuberosity (AIT) and of the surface area of the iliac tuberosity (SIT), utilized for the regression equations and for their validation

	Mean±s.d.	Range
Regression		
BCS	6.71±0.77	5.0–8.0
AIT (°)	143.58±5.9	127–154
SIT (cm^2)	355.70±23.34	315–397
Validation		
BCS	6.62±0.68	5.0–7.8
AIT (°)	142.78±5.51	131–153
SIT (cm^2)	352.44±22.20	318–394

Table 6
Regression equations[a] between body condition score (Y), angle of the iliac tuberosity (X_1), surface area of the iliac tuberosity (X_2)

Regression	a	b_1	b_2	R^2	Rmse
4]	−9.6426	0.1139		0.77***	0.37
5]	−3.7714		0.0295	0.81***	0.34
6]	−7.4026	0.0537	0.0180	0.85***	0.30

Validation	BCS_{VIA}	$Diff_{alg}$	$\%_{alg}$	$Diff_{abs}$	$\%_{abs}$	<4.5%	4.5–9.0%
4]	6.62±0.63	0.01	−0.08	0.26	3.89	68%	32%
5]	6.61±0.65	0.01	0.01	0.27	3.99	60%	40%
6]	6.61±0.67	0.02	0.16	0.21	3.12	72%	28%

Validation of the regression equations.
***$P<0.001$.
[a] $Y=a+b_1*X_1+b_2*X_2$ where X_1=AIT, X_2=SIT.

(3.89%) and 0.27 points (3.99%) were obtained, respectively. With regard to the distribution of individual differences between evaluated and VIA-estimated BCS, they never exceeded 9%; so two classes were identified: <4.5% and 4.5–9%. In both simple equations, a distribution of at least 60% was recorded in the best class. To further improve determinations, multiple regression Eq. (6) BSC=−7.4026+0.0537 AIT+0.0180 SIT was used and proved to be highly significant ($P<0.001$) with a determination coefficient of 0.85. Mean difference, in absolute value, between evaluated and calculated (Eq. (6)) BCS was 3.12% or 0.21 points. The distribution of individual difference was better compared to that obtained with Eqs. (4) and (5), with 72% of the sample within class <4.5%.

The results show that, for the objective determination of BCS, both AIT and SIT provide an adequate estimate. As for the indirect determination of weight, the use of these parameters also led to a further improvement in the degree of precision, reducing, for the individual animals, the differences between the estimates of the degree of fattening and objective evaluations obtained by opto-informatics. Following an extensive bibliographic search, no specific data were found relating to the application of Visual Image Analysis in determining the degree of fattening (BCS), either for buffaloes or other species of zootechnical interest. Thus, a comparison with data from other studies was not possible.

4. Conclusion

The results demonstrated that Visual Image Analysis permits the acquisition of accurate and rapid morphometric measurements in the buffalo. The system also makes it possible to effect measurements which would otherwise be impossible with traditional zootechnical biometric tools, such as measurement of surface areas and angular values. These parameters proved valid for the indirect determination of live weight and the objective determination of the degree of fattening by a photographic survey of the side and hindquarters of the animal. A single photographic survey is sufficient to obtain, with precision, the indirect determination of live weight and the objective determination of BCS, utilizing simple linear regression equations. Two photographic surveys (lateral and hindquarters) allow for the use of multiple regression equations, which increase the degree of precision both for indirect determination of live weight and the objective determination of the degree of fattening.

References

Barrey, E., Desliens, F., Poirel, D., Biau, S., Lemaire, S., Rivero, L.L.J., Langlois, B., 2002. Early evaluation of dressage ability in different breeds. Equine Vet. J. 34, 319–324.
Bergero, D., 1996. Determinazione indiretta del peso del cavallo da sella. Obiettivi Doc. Vet. 2, 69–72.
Borggard, C., Madsen, N.T., Thodberg, H.H., 1996. In line image analysis in the slaughter industry, illustrated by beef carcass classification. Meat Sci. 43, 151–163.
Bourgelat, C., 1768. Traité de la conformation extérieure du cheval. Printed in Lione, Ffurther details needed.
Campanile, G., De Filippo, C., Di Palo, R., Taccone, W., Zicarelli, L., 1998. Influence of dietary protein on urea levels in blood and milk of buffalo cows. Livest. Prod. Sci. 55, 135–143.
Elting, E.C., 1926. A formula for estimating surface area of dairy cattle. J. Agric. Res. Washington 33, 269–279.
Frape, D., 1986. Equine Nutrition and Feeding. Longmans Scientific & Technical, Harlow, UK.
Filippi Balestra, G., Negretti, P., Tonielli, R., 1994. Analisi d'immagine nella valutazione morfologica della bovina da latte. Proc. 48th S.I.S.Vet. Congr., pp. 1561–1565.
Greiner, S.P, Rouse, G.H, Wilson, D.E., Cundiff, L.V., Wheeler, T.L., 2003. Prediction of retail product weight and percentage using uTR.L.asound and carcass measurements in beef cattle. J. Anim. Sci. 81, 1736–1742.
Goubaux, A., Barrier, G., 1884. De l'extérieur du Cheval. Asselin et Cie, Paris.

Kuchida, K., Hamaya, S., Saito, Y., Suzuki, M., Miyoshi, S., 1996. Development of a body dimension measurement method for dairy cattle by computer image analysis with video camera. Anim. Sci. Techol. 67, 878–881.

Lecocq, F., 1840. Traité de l'extérieur du cheval et de principaux mammifères domestique. Printed in Lione, F.

Magliano, A., 1930. Ezoognosia Generale. Torinese, Torino.

Mascheroni, E., 1897. Determinazione del peso vivo dei bovini col nastro misuratore di Matiévitch. Moderno Zooiatro.

Mastrolilli De Angelis, A., 1942. Metodo approssimativo, per la determinazione del peso corporeo negli equini e nei bovini. Il monitore tecnico, vol. I.

Martin Rosset, W., 1983. Particularité de la croissance et du développement du cheval. Ann. Zootech. 32, 109–130.

Martin Rosset, W., Dubroeucq, H., 1988. Evolution du format du cheval de selle de la naissance a 18 mois: critères et méthodes d'appréciation. Proc. 14eme Journée d'étude CEREOPA.

Milner, J., Hewitt, D., 1969. Weight of horses: improved estimates based on girth and length. Can. Vet. J. 10, 314–316.

Negretti, P., Bianconi, G., 1999. Utilizzo del telemetro laser nel rilevamento morfologico computerizzato dei bovini da carne. Taurus 11, 57–66.

Negretti, P., Bianconi, G., 2001a. Determinazione del peso vivo sul cavallo con l'analisi d'immagine. Proc. 3th Società italiana di Ippologia Congr., vol. 3, pp. 125–132.

Negretti, P., Bianconi, G., 2001b. Determinazione indiretta della resa alla macellazione sul vivo dei bovini da carne chianina mediante rilevamenti di tipo opto-informatico. Taurus 12, 115–124.

Negretti, P., Bianconi, G., 2004. Morphological survey through computerised image analysis. Proc. 7th World Conf. Brown Swiss Cattle Breeders, pp. 195–201.

Negretti, P., Bianconi, G., 2005a. Indirect determination of live weight, dead weight, and yield at slaughtering of chianini beef by means of opto-informatic evaluation methods. Proc. 4th World It. Beef Cattle Congr., pp. 229–234.

Negretti, P., Bianconi, G., 2005b. Determination of horse morphology and weight by means of computerised image analysis. Proc. 7th Conf. on New findings in Equine Practices, pp. 146–148.

Paci, C., 1947. Zoognostica. Cisalpino, Milano.

Paragon, B.M., Blanchard, G., Valette, J.P., Medjaoui, A., Wolter, R., 2000. Suivi zootechnique de 430 poulains région Basse-Normandie. Croissance pondérale staturale et estimation du poids. Les haras nationaux. Proc. 26eme Journée de la recherche équine, pp. 3–7.

Roussy, B., 1922. La mesure de la surface cutanée du cheval. C. R. Acad. Sci. 3, 195–196.

Sanson, A., 1886. Trattato di Zootecnia. Fratelli Dumolard, Milano.

Sakowski, T., Cytowski, J., 1996. Video image analysis was employed to evaluate carcass composition of live cattle. Stocarstvo 50, 205–208.

SAS (Statistical Analysis System Institute), 1993. SAS User's Guide, Statistics. SAS Institute Inc., Cary, NC, USA.

Tamaro, D., 1901. Istruzione popolare per la scelta degli animali bovini. C. Cassone, Casale Monferroni.

Tözsér, J., Sutta, J., Bedö, S., 2000. The evaluation of video pictures for measurements of cattle. Állatteny. Takarm. 49, 385–392.

Wagner, J.J., Lusby, K.S., Oltjen, J.W., Rakestraw, J., Wettemann, R.P., Walters, L.E., 1988. Carcass composition in mature Hereford cows: estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66, 603–612.

White, R.P., Schofield, C.P., Green, D.M., Parsone, D.J., Whittemore, C.T., 2004. The effectiveness of a visual image analysis (VIA) system for monitoring the performance of growing/finishing pigs. Anim. Sci. 78, 409–418.

Wolter, R., 1994. Alimentation du cheval. France Agricole, Paris.

Zehender, G., Cordella, L.P., Chianese, A., Lino Ferrara, A., Del Pozzo, A., Barbera, S., Bosticco, A., Negretti, P., Bianconi, G., Filippi Balestra, G., Tonielli, R., 1996. Image analysis in morphological animal evaluation: a group for the development of new techniques in zoometry. Anim. Genet. Resour. Inf. 20, 71–79.