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POSSIBILITIES OF USING MORPHOMETRIC MEASUREMENTS AS A TOOL TO ESTABLISH A LIVE BEEF CATTLE GRADING SYSTEM IN TUNISIA

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ABSTRACT

In the present study, a total of 273 bulls between 12 and 26 months of age were studied using morphometric measurements in order to establish a cattle grading system for beef cattle in Tunisia. The bulls were mainly Holstein (169), Limousin (16), Charolais (58), Salers (11), and crossbred animals (19). Measurements of the height at withers (WH) and pelvis (PH), the width (CW) and girth of the chest (CG), the width at pelvis (PW), and the depth of chest (CD), in addition to the weight and age at slaughter, were recorded. Statistical evaluations were made using of the principal component analysis (PCA) as well as a Ward's cluster analysis (WCA). High correlations were recorded between the weight, the width at pelvis ($r = 0.90$), the chest width ($r = 0.89$), and the chest perimeter ($r = 0.89$). Principal components analysis identified two main components that could characterize the carcasses. Ward's cluster analysis based on the two main components displayed the presence of four groups of bulls defined as following: (1) bulls with a low conformation and a small frame size, (2) bulls with a medium conformation and a large frame size, (3) bulls with fairly good conformation and a small frame size, and (4) bulls with a good conformation and a large frame size. Consequently, live weight and the height at withers can be used as the main measurements to establish a live cattle grading grid in Tunisia including a combination of live weight (light or heavy) and withers height (tall or short).

Keywords: Bulls, live measurements, classification, principal component, cluster analysis.

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INTRODUCTION

Several classification systems for live cattle are used in many different countries in order to evaluate the carcass value of live animals and carcasses based on several criteria (Règlement Européen n°1208/81, 1981; Canadian Beef Grading Agency, 1992; USDA, 1979; USDA, 1997; Meat & Livestock Australia Limited, 2017). These systems establish a fair market and transparent prices for the animals sold in the livestock market in accordance with their muscling conformation, fat score and frame size (USDA, 1979; Meat & Livestock Australia Limited, 2017). In Tunisia, animal transactions take place mainly through subjective evaluations of young bulls with no objective measures or a classification grid. A classification system of living bulls on the basis of objective measures is still needed to define various market classes and ease commercial transactions between various operators in the red meat industry in the country.

Several authors used the morphometric measurements as a tool to characterize carcasses and living animals (Brown *et al.* 1973; Destefanis *et al.* 2000; Alberti *et al.* 2005; Santos *et al.* 2008). Fisher (1975) reported that morphometric measurements taken from live animals provided a simple method for recording biological parameters relevant to the shape and potential growth. Several researchers established relationships between linear body measurements on live animals and carcass characteristics such as slaughter grade, carcass grade, and dressing percentage (Kohli *et al.* 1951; Cook *et al.* 1951; Kidwell 1955; Tallis *et al.* 1959). Earlier studies were also conducted to reveal the relationship between body measurements and conformation score or frame size and shape (Ternan *et al.* 1959; Tatum *et al.* 1986).

Morphometric measurements were used by several authors to describe animal morphology of different cattle such as Brahman, Zebu and Sahiwal breeds (Alsiddig *et al.* 2010; Rashid *et al.* 2016; Khan *et al.* 2018).These studies have utilized body measurements such as body length, height at withers, rump width, and height at hooks to characterize cattle local breeds and estimate their heritability. Others researchers performed body measurements in cattle to estimate the live weight of indigenous breeds in Bangladesh, Sudan and Philippine (Bagui and Valdez 2007; Abdelhadi and Babiker 2009; Rashid *et al.* 2016). These research cases focused on the relationship between linear body measurements such as heart girth, body length, hip height, canon width, height at withers and live weight in cattle. Regression equations for the prediction of live body weight from linear body measurements have been also determined. Several previous studies have reported the use of subjective methods to characterize live animals according to the classification systems established in many countries

(Canada, USA, Australia and Europe). There is insufficient literature on the use of morphometirc measurements to establish a live cattle grading system. The first step of the development of a live cattle grading system is to identify the morphological characteristics of animals either using subjective or objective measurements. The main objective of this paper was to study the possibility to use objective measurements as a tool to establish a live cattle grading system for bulls aged between 12 and 26 months in Tunisia. This paper adds to the data and advances the analysis previously published (Slimene *et al.* 2012). Principal components analysis identified measurements that characterize live bulls and a cluster analysis based on the identified components was used to identify the main classes of live bulls that could be present in the Tunisian livestock markets.

MATERIALS AND METHODS

Animals and collected data: A total of 273 young bulls were used in this study. They were divided between local dairy type (169) Holstein, imported pure breed beef (85), and crossbred beef animals (19). Beef breeds were: Limousine (16), Charolais (58), and Salers (11). Local dairy breed cattle were fed oat silage, hay, and a concentrate formulated at the farm. Imported beef breed cattle were fed straw and concentrate formula based upon nutrient required by the animals. Details pertaining to animal identification, herd number, breed and birth date were obtained from the national database of animal identification managed by the Tunisian Ministry of Agriculture, either for local and imported beef breed cattle. In general, local dairy breed feeder cattle could come from two main production systems a large-scale dairy cattle intensive system and the landless small-scale dairy cattle system composed by Holstein. However, imported beef breed feeder cattle could come either from Europe or South American countries. Live weights averaged 437.69 kg and 669.69 kg respectively, for local dairy type Holstein and imported beef breed cattle. Holsteins were slaughtered at an average age of 17.06 months and beef breed cattle had an average of 19.70 months at slaughter.

Live measurements: Data recorded on live animals were the weight (LW) and the age at slaughter. Measurements were recorded in a restraining compartment in the farm one day prior to the slaughter. At each measurement, care was taken to have the animal standing in a natural position on a level surface. Measurements were recorded according to the method of De Boer *et al.* (1974):

- Withers height (WH): measured from the highest point of the withers, between the shoulders,
- Pelvis height (PH): measured from the anterior edge of the sacrum between the hips,
- Chest width (CW): width immediately behind the shoulder blades,
- Chest depth (CD): measured behind the shoulder at the same level as width of chest,
- Chest girth (CG): smallest circumference measured behind the shoulder at the same level as width and depth of chest,
- Pelvis width (PW): measured at trochanters,

These measurements were done throughout by one person. Perimeter measurements were taken by tape measure, whereas width, depth and height measurements were taken by caliper. All procedures of this experiment were conducted according to the guidelines of the Tunisian livestock law No.2005-95 regarding breeding and slaughtering.

Statistical analysis: Statistical analyses were performed by SAS software, version 9.1. Simple correlations among measurements were determined using PROC CORR followed by an analysis of the principal components (PCA) which aimed to identify variables (LW, WH, CG, PW, CD and CW) that characterize different groups using PROC PRINCOMP. To avoid ghost effects on the PCA due to different measurement scales, the variables for PC analysis were standardized on the basis of (zij = (xij - averagej)/ (standard deviation) j) to a mean of zero and variance of one, to give each variable equal weight in the statistical analysis. Two principal components were retained where the eigenvectors are greater or equal to one. Ward's cluster analysis based on the two principal components was employed and the function PROC CLUSTER to create a dendrogram that distinguishes between different classes of living animals. Finally, statistically significant differences among the different cluster groups were tested using the PROC GLM with 5% level of significance ($P \leq 0.05$). Significance of the differences between the different clusters was determined with the Duncan's test.

RESULTS AND DISCUSSION

Descriptive parameters and correlation analysis: Descriptive statistics of the measurements are shown in Table 1. The CV of some measurements, such as height at withers, height at pelvis, depth of chest, and girth chest, was lower than 10%, while for some others, like width at pelvis, width of chest, live weight, and age at slaughter the CV were higher. These results were similar to those reported by Kidwell (1955) for withers height, chest depth, and pelvis height measurements in Hereford steers. However, the other measurements had higher CV except for live weight which had a lower value. Compared to values reported in this study, Ternan *et al.* (1959) found lower coefficients of variation in beef cattle yearling steers. The dairy breed (Holstein) had a higher withers height 131 cm, while the beef breeds had a shorter height (129 cm).

Table 1. Means, standard deviations (S.D), and coefficients of variation (C.V) of the measurements of different breeds (dairy n=169; beef n=104).

Breed	Dairy					Beef				
Measurements	**Mean**	**S. D**	**C.V**	**Min**	**Max**	**Mean**	**S. D**	**C.V**	**Min**	**Max**
Slaughter live weight (kg)	437.69	44.16	10.08	350	600	669.69	45.92	4.00	534	828
Slaughter age (month)	17.06	2.79	15.87	12	26	19.70	1.91	9.72	15	25
Withers height (cm)	131.82	4.33	3.28	120	144	129.76	4.32	3.33	121	139
Chest width (cm)	40.18	2.76	6.88	33	49	69.13	2.49	5.37	64	77
Pelvis height (cm)	136.01	4.23	3.11	122	147	137.61	4.79	3.48	125	149
Pelvis width (cm)	46.90	2.45	5.22	41	54	60.76	3.23	5.32	50	68
Chest depth (cm)	68.34	2.49	3.64	62	76	69.13	2.49	3.60	64	77
Chest girth (cm)	176.65	7.06	7.19	162	195	200.65	5.48	2.73	185	212

Holstein had a small chest girth (176.65 cm) and live weight (437.69 kg) whereas beef breeds had the greatest values (200.65 cm and 669.69 kg). When the relationship was found between breeds using the traits, withers height and chest girth, three main groups can be found according to the frame size (Fig. 1), there were Charolais, Limousin and cross breeds characterized by their medium withers height and high chest girth or live weight (Charolais had the lower value for withers height), Salers was considered as a tall breed with the greatest height at withers, and tall dairy breed (Holstein) with a lower chest girth and live weight. Alberti *et al.* (2008) found high significant differences between breeds (Charolais, Limousin and Holstein) in withers height adjusted to 365 days of age. Holstein was recorded as the highest wither's heights. McGee *et al.* (2007) reported higher value for withers height measured on Holstein compared to Charolais at the same slaughter weight. These findings explained in a certain part the results found in the present study, which indicated that breeds with lower withers height had the greatest chest girth.

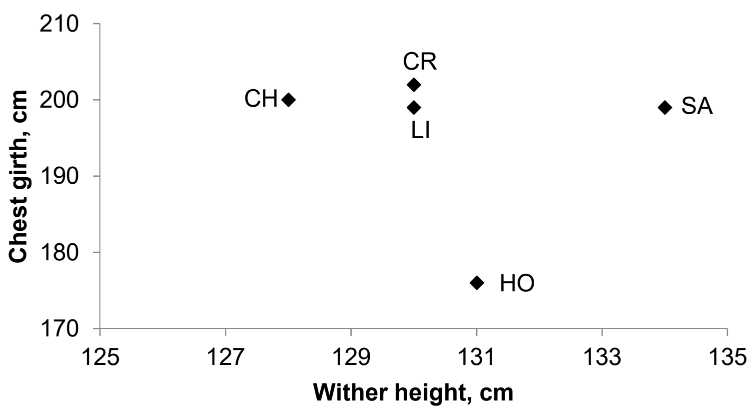

Fig. 1. Cattle breeds means for live measurements (chest girth and withers height) performed in animals before slaughter. HO: Holstein (n=169); CR: Crossbred beef (n=19); LI: Limousine (n=16); CH: Charolais (n=58); SA: Salers (n=11)

Correlation coefficients between pairs of the eight studied variables are shown in Table 2. Weight had a high positive correlation with the perimeter of the chest (r = 0.89), the width of the chest (r = 0.89), and at pelvis (r = 0.90) ($P<0.05$). These results were similar to those reported by Tatum *et al.* (1986) and Kidwell (1955). The findings of Ozkaya and Bozkurt (2009) showed that live weight predicted by regression equation that included withers height measurements had higher determinant coefficient (R^2) in Brown Swiss and crossbred than Holstein. In the present study, withers height was recorded just before the slaughter and animals had different ages and slaughter weights. Correlations between withers height and live weight within the breed type were positive (r = 0.30 and r = 0.44 for beef and dairy breed respectively). In addition, negative correlation (r = - 0.06) between the live weight and height at withers for the all breeds was also recorded.

Tatum *et al.* (1986) recorded a high positive correlation for these last two parameters. Similarly, the chest perimeter showed a high positive correlation with the chest width (r = 0.90) and width at pelvis (r = 0.89)

(P<0.05). Width at pelvis was highly correlated with width of chest (r = 0.91) (P<0.05).

Table 2. Correlations among live measurements (n=273).

Parameters	Age	LW	CD	CG	CW	PW	WH
Age							
LW	0.49**						
CD	0.30**	0.26**					
CG	0.54**	0.89**	0.37**				
CW	0.38**	0.89**	0.22**	0.90**			
PW	0.44**	0.90**	0.23**	0.89**	0.91**		
WH	0.30**	-0.06	0.52**	0.04	-0.14*	-0.12*	
PH	0.43**	0.31**	0.49**	0.21**	0.21**	0.27**	0.71**

$^{**}P< 0.001$, $^{*}P< 0.01$. Live weight (LW), chest depth (CD), chest girth (CG), chest width (CW), pelvis width (PW), withers height (WH), and pelvis height (PH).

The findings of Brown *et al.* (1956) were in disagreement with those recorded in the present study; mainly those related to the Pearson correlation between the body weight and height at withers and the chest depth. The Pearson correlation between the depth of the chest and the body weight reported in the present study was significantly lower (r = 0.26 vs. r = 0.67) than the correlation reported by Brown *et al.* (1956). Wanderstock and Salisbury (1946) reported similar high correlations between weight at slaughter and height at withers and heart girth. However, Yao *et al.* (1953) reported low correlations between the variables related to the height at hooks, the width of the chest (r = -0.07) and the width at pelvis (r = 0.17). These earlier results were in agreement with the low correlations estimated in the present study. Kohli *et al.* (1951) reported a high positive correlation between the height of the chest and height at withers (r = 0.75) and a negative correlation between width of shoulders and height at withers (r = -0.25). These results are not in concordance with those recorded in the present study.

Principal component analysis (PCA): The results of principal components are summarized in Table 3 for the two principal components (PC) extracted from raw variables. The first component explained 54.18% of the variability among animals, while the second component explained only 26.07%. Both components explained 80.25% of the total variability in cattle morphological data.

Table 3. PCA Results of the different body measurements (n=273).

Measurements	CP1	CP2
Age (month)	0.64	0.26
Live weight (kg)	0.92	-0.26
Chest depth (cm)	0.46	0.59
Chest girth (cm)	0.95	-0.12
Chest width (cm)	0.89	-0.35
Pelvis width (cm)	0.91	-0.31
Pelvis height (cm)	0.52	0.70
Withers height (cm)	0.16	0.92
Eigenvalue	4.33	2.08
Portion of variance (%)	54.18	26.07
Cumulative variance (%)	54.18	80.25

Very strong correlations of the first component with the weight (r = 0.92), chest perimeter (r = 0.95), pelvis width (r = 0.91), and chest width (r = 0.89) were recorded in the present study. The second component presented very strong correlations with the withers height (r = 0.92) and pelvis height (r = 0.70). Alberti *et al.* (2008) implemented a principal component analysis using the data of 15 European beef breeds reported that the first component explained about 48% of variance however, the second component accounted for 24% of total variability. These results are quite similar to those found in our study.

The eight variables in the plane formed by the axes representing the two main components 1 and 2 are presented in Figure 2. The coordinates of these variables are the correlations of variables with the components 1 and 2. Component 1 was positively and highly correlated with the weight, the chest width, the pelvis width, and the chest girth, whereas a negative correlation was shown with the withers height.

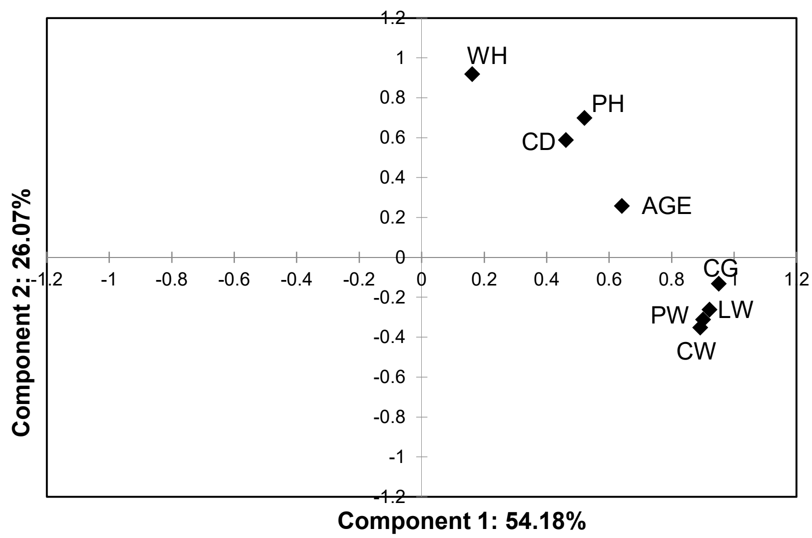

Fig. 2. Projection of the morphometric measures in the plane defined by the two first components (PCs loading plot). LW: live weight; CD: chest depth; CG: chest girth; CW: chest width; PW: pelvis width; WH: withers height; PH: pelvis height.

In addition, conformation in live cattle is considered as a subjective evaluation of thickness of natural fleshing or muscling. In fact, De Boer *et al.* (1974) defined conformation as thickness of flesh and subcutaneous fat relative to the dimension of the skeleton. The second component was positively and highly correlated with the height at withers, the height at pelvis and the chest depth of the living animal (P<0.05). Hence, the principal component analysis identified two groups of raw variables and allowed a way to visualize the relationships among them. The first main component is correlated with variables related to the appearance of the live animal and thickness which can be considered as conformation while the second is related to the skeletal structure that can be considered as a skeleton size indicator.

The agglomeration of the 273 live animals displayed the dendrogram reported in Fig. 3 revealed the existence of four clusters. Cluster 1 and 2 included the dairy breed cattle recording low values in live weight and width but are different in height. However, animals assigned to the clusters 3 and 4 were found to be mainly beef breed cattle characterized by a high live weight and width and different in height.

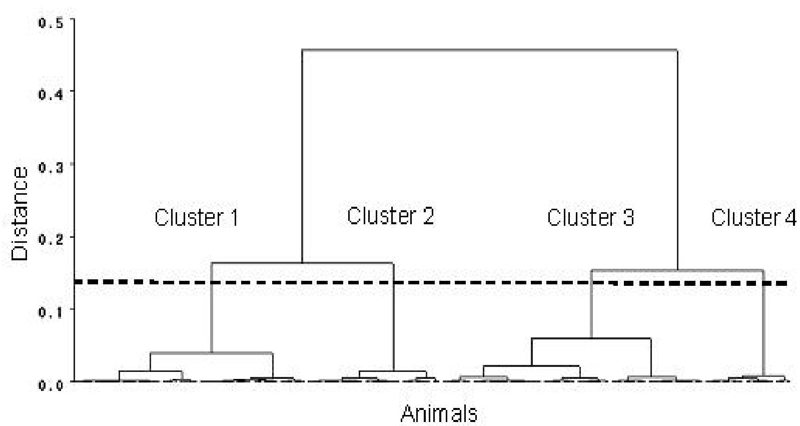

Fig. 3. Dendrogram resulting from cluster analysis grouping live animals in four classes according to the morphometric traits.

Cluster analysis: Results of Ward's cluster analysis are depicted in Figure 4. Cluster analysis based on two previously identified components permitted the determination of four classes of live animals that could be described as following:

- Cluster 1: Bulls with a live weight between 300 and 550 kg, withers height between 125 and135 cm, and a chest perimeter between 165 and 190 cm.
- Cluster 2: Bulls with a live weight between 300 and 550 kg, withers height between 135 and 145 cm, and a chest perimeter between 165 and 190 cm.
- Cluster 3: Bulls with a live weight between 550 and 850 kg, withers height between 120 and 130 cm, and a chest perimeter between 190 and 210 cm.
- Cluster 4: Bulls with a live weight between 550 and 850 kg, withers height between 130 and 140 cm, and a chest perimeter between 190 and 210 cm.

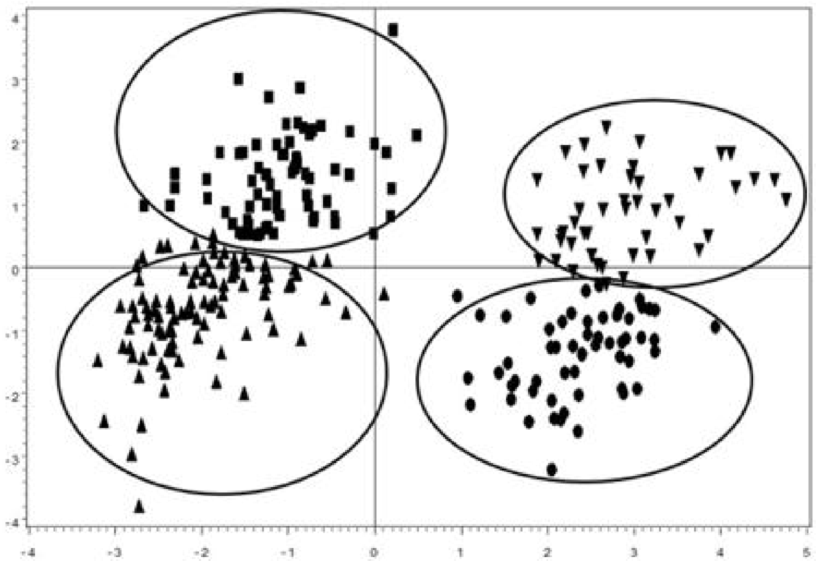

Fig.4. Projection of the morphometric measurements of the four animal groups identified by the cluster analysis based upon the two principal components using the "Ward" method (score plot) and the grouping level (dashed line) as it is shown in the dendrogram. ▲: cluster1, ■ :cluster 2, ● : cluster 3, ▼ : cluster 4.

Average values of live measurements for each of the four clusters are shown in Table 4. Bulls belonging to the cluster 2 had higher measurement values compared with those in the cluster 1. Most measurements differed significantly among clusters. Bulls in cluster 2 were older compared to those in cluster 1 (19 months vs. 16 months). In addition, bulls in cluster 2 had higher values for live weight (459 kg vs. 422 kg), chest girth (181 cm vs. 173 cm), pelvis width (48 cm vs. 46 cm), withers height (136 cm vs. 129cm), and pelvis height (140 cm vs. 133 cm) compared with those in the cluster 1. Animals grouped in cluster 1 and 2 were mainly dairy breeds and had a weight range between 350 and 600 kg whereas those in cluster 3 and 4, beef type breeds had a weight range from 534 to 828 kg. Bulls in the cluster 4 showed the same trend compared to those in the cluster 3. In fact, bulls in cluster 4 recorded higher values for the live weight compared the cluster 3 (678 kg vs. 663 kg). They also had higher values compared to bulls in cluster 3 for the following measurements: withers height (134 cm vs. 127 cm), pelvis height (142 cm vs. 134 cm), chest depth (71 cm vs. 68 cm), and chest perimeter (202 cm vs. 199 cm).

In discussion, the findings reported by Black and Knapp (1937) showed similar trend to those reported in this study. Different clusters showed that measurements recorded for height and width increase with animal age. Tatum *et al.* (1986) applying the livestock grading system for beef cattle and reported higher frame score for animals when an increase in withers height and pelvis were registered. They also reported higher values of muscling score for animals having higher measurement values for their chest width, girth and live weight. These results are similar to those found in our study moving from the cluster 1 and ending up with the cluster 4. The feeder cattle grades and standards established in the US presents three frame size grades and four thickness levels. The final grade assigned to the animal is a combination of the two criteria (USDA, 1979). In Tunisia the live cattle could be given a subjective grade by considering two frame size score and two live weight classes. The final standard or grade would be a combination of both scores which results in four different animal groups as it is found in our study.

Table 4. Means and standard errors of measurements by class of live bulls (n=273).

Parameters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	SEM
Number of animals	97	72	58	46	-
Breed type	1	1	2	2	-
Breed proportion within clusters (%)	57	43	56	46	-
Age (month)	16[a]	19[b]	19[b]	20[c]	0.16
Live weight (kg)	422[a]	459[b]	663[c]	678[d]	7.34
Chest width (cm)	40[a]	41[a]	54[b]	55[b]	0.45
Pelvis width (cm)	46[a]	48[b]	60[c]	61[c]	0.44
Withers height (cm)	129[a]	136[b]	127[c]	134[d]	0.26
Pelvis height (cm)	133[a]	140[b]	134[c]	142[d]	0.27
Chest depth (cm)	67[a]	70[b]	68[a]	71[c]	0.15
Chest girth (cm)	173[a]	181[b]	199[c]	202[d]	0.80

[a,b,c,d] Row means with different superscripts differ significantly at $P < 0.05$.
SEM standard error mean.
1: Dairy type, 2: Beef type

Conclusion: This study used principal component analysis followed by cluster analysis to categorize young bulls in Tunisian markets into four groups to establish a live beef cattle grading system. Categorization of morphometric measurements provides producers and butchers with a simple system that makes transactions more transparent and reflects the values of bulls in Tunisian livestock markets. Live weight and the height at withers can be used as the main measurements to establish a grading grid. In practice, a technical guide will be developed showing figures of the different category characteristics which include a combination of live weight (light or heavy) and withers height (tall or short). Dentition could be also included in the grading system. This will serve as a basis for the negotiation among professional operators in the red meat sector at the level of the livestock market and ease the sale transactions of bulls for slaughter.

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