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BEEF CARCASS GRADING STANDARDS DEVELOPMENT USING MORPHOMETRIC MEASUREMENTS IN TUNISIA

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ABSTRACT

The main objective of this study was to characterize carcasses of slaughtered bulls in order to develop a carcass grading standard. Two hundred thirty carcasses were evaluated morphometrically for conformation and fatness. The breeds were Holstein, Limousin, Charolais, and crossbred beef bulls. Carcass measurements recorded at the slaughterhouse were: carcass length, hind leg perimeter, carcass depth, hind leg length and thickness. Hot carcass weight, fat thickness at the sixth rib and kidney fat weight were recorded. Principal component analysis and cluster analysis were performed to characterize carcasses. Analysis of variance was also performed to determine significant difference between the four classes of carcasses identified in this study. Results showed four groups of carcasses described as follows: (1) low weight and small size carcasses, (2) average weight and large size carcasses, (3) heavy weight and small size carcasses, (4) heavy weight and large size carcasses. In conclusion, weight and length of the carcass can be used as the main measurements to establish a carcass grading grid in Tunisia.

Keywords: Carcass measurements, bulls, classification, component analysis, cluster analysis.

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INTRODUCTION

Several countries worldwide have established systems of cattle carcasses classification to a better balance between the purchase price and the carcass value. These different systems are based on assessing the carcass by using measurements or visual appraisal of trained person working in the slaughterhouse. The system used in the European countries uses two main parameters. The first one is conformation and the second is fatness degree using a template grid developed by professionals. In the United States the system is composed of two grades, the quality grade includes marbling and maturity and the yield grade includes the hot carcass weight, fat thickness, kidney fat percentage and rib eye area. Other countries like Japan, Australia and Canada have identified several measurements similar to those used in the US to allow a better assessment of carcasses conformations and marketing prices. In Tunisia, however, there is no carcass classification grid used in either the slaughterhouse or in the meat processing plant. Butchers make their transactions mainly through a subjective assessment of fattening degree and conformation. Hence, there is a need to develop a carcass classification system based on objective measurements that consider the criteria taken into account by butchers.

Several authors used a multivariate and a principal component analysis to characterize carcasses from many species such as beef cattle, sheep and goats. (Santos *et al.,*2008 ; Alberti *et al.,* 2005; Destefanis *et al.,* 2000; Laville *et al.,* 1996; Spanghero *et al.,* 2004; Alberti *et al.,* 2008). Others used carcass measurements such as carcass length, chest depth, rump and arm length, rump and arm circumference, carcass weight and composition, conformation and fat scores including meat proportions to characterize carcasses of several breeds at distinct ages and to identify variability between dairy and beef breeds. (Clarke *et al.,* 2009; Campion *et al.,*2009; Yilmaz *et al.,* 2009; Venkata *et al.,* 2014; Domingo *et al.,* 2014 ; Coleman *et al.,* 2016 ; Nogalski *et al*., 2017). Measurements on the beef carcasses were taken to establish carcass cutability. (Busch *et al.,* 1968; Abraham *et al.,* 1968; Epley *et al.,* 1970; Cross *et al.,* 1973 ; Addis *et al.,* 2020; Seo *et al .,* 2021).

The main objective of this research paper was to study the possibility to characterize carcasses using objective measurements to establish a carcass 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). Cluster analysis was used to identify the main carcass classes that could be available in the red meat sector.

MATERIALS AND METHIODS

The experiment was undertaken according to the specific guidelines described in the Tunisian regulations

(Livestock law No 2005-95) with regards to breeding and slaughtering.

Animal and collected data: A total of 230 bulls selected randomly were slaughtered in two small commercial plants to characterize their carcasses. The two small commercial plants are located in the northern region of the country and kill an average of 15 heads per day. Animals used in this study were Holstein (169), Limousin (13), Charolais (35), and crossbred (CharolaisxLimousin, LimousinxSalers and CharolaisxSalers) beef bulls (13). Oat silage, hay, and concentrate were offered to Holstein cattle. Beef breed cattle received straw and concentrate. Animal identification and birth date were collected 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 dairy farm using intensive system and the landless small dairy rearing system composed by Holstein. However, imported beef breed feeder cattle could come either from Europe or South American countries. Holstein bulls were slaughtered at an average age of 18 months and the beef breeds were at an average of 19 months. Holstein had an average of 437.69 kg whereas beef breeds had 671.70 kg as average slaughter weight. Average carcass weights recorded were 227 kg, 409 kg, 418 kg, 414 kg, respectively, for Holstein, Charolais, Limousin and crossbred beef bulls.

Carcass measurements: Slaughter procedures and postmortem inspection of the carcass were conducted according to the regulation of the Tunisian Ministry of Agriculture. Bulls were slaughtered according to the Muslim rite. Hot carcass weights were recorded before the chilling process at 2°C. Hot carcass weights averaged 227 kg, 409 kg, 414 kg and 418 kg, respectively, for Holstein, Charolais, Crossbred beef and Limousin. Dressing percentage was determined as (hot carcass weight/slaughter live weight) *100.

The data included the slaughter age; hot carcass weight (CW); kidney fat weight (FKW); and the degree of fat thickness (FC). Immediately after carcass split along the midline, measurements were recorded from the left-side of the carcass as prescribed by De Boer *et al.* (1974) and explained by Alberti *et al.* (2005):

- Length of the carcass (LC), distance from the internal side of the symphysis pubis to the internal edge at the middle of the first rib.
- Length of the hind leg (LL), distance from the distal end point of the tibia to the internal side of the symphysis pubis.
- Depth of the carcass (DC), horizontal distance from the internal edge of the breast bone to the internal side of the back bone at the level of the sixth rib.
- Depth of the hind leg (DL), horizontal distance from the end points on the internal and the external side of the leg.
- Perimeter of the leg (PL), horizontally circumference of the leg taken at the level of the symphysis pubis.

The carcass measurements using tape included length and perimeter, whereas width, depth and fat thickness were taken by caliper. These measurements were done throughout by one person. From measurements mentioned above carcass compactness index was determined as follows: carcass compactness = carcass weight*100 ÷ carcass length (Alberti *et al.*, 2005).

Tissue composition: The sixth thoracic rib joint was extracted randomly from 104 carcasses representing the four studied breeds. The weight of the rib was recorded at 24 h postmortem. Muscle, fat and bone were separated according to the method prescribed by Robelin and Geay (1975).

Statistical Analyses: Statistical analyses were performed using SAS (2002). Simple correlations were also determined using the PROC CORR for all the variables measured on the carcass (LC, LL, DC, DL, PL, CW, FC, and FKW). Principal component analysis was performed using PROC PRINCOMP for all the variables measured on the carcasses to determine the number of independent variables to distinguish among different groups of carcasses. The variables for PC analysis were standardized according to the normal distribution. In this analysis, two principal components retained with eigenvectors are greater than or equal to 1. Cluster analysis on principal components using the "WARD" method was conducted using the function PROC CLUSTER to identify the different groups of carcasses. Analysis of the variance was conducted using the procedure PROC GLM to determine if differences among the four classes of carcasses were significant ($P<0.05$).

RESULTS AND DISCUSSION

Descriptive parameters and correlation analysis: Means, standard deviations and the coefficient of variation of the carcasses are given in Table 1. The coefficient of variation of some variables, such as carcass length (LC), leg length (LL), and depth of the carcass (DC), is lower than 10%, while some others, like fat thickness (FC), weight of kidney fat (FKW), carcass weight (CW), is higher than 30%. These results were quite similar to those observed by Alberti *et al.* (2005) for measurement recorded for carcass length, leg length and leg perimeter. Laville *et al.* (1996) found similar coefficient of variation for carcass length, leg length and carcass depth. However, results reported by Dernnan *et al.* (2008) were lower especially for fat thickness. Coefficients of correlation among carcass traits are shown in Table 2. Correlations between carcass weight and leg depth (r = 0.89) and perimeter were significantly high (r = 0.91). However, depth of carcass showed a negative correlation between all variables except for both length parameters such as leg length (r = 0.28) and carcass length (r = 0.22). High positive correlations were found between carcass weight, fat cover (FC) (r = 0.83) and dressing percentage (r = 0.92). Alberti *et al.* (2005) reported similar results for the correlation between the leg.

Table 2. Correlations among carcass measurements.

	AGE	LC	DC	LL	LD	PL	CW	FKW	FC	DP	CCI
AGE											
LC	0.54**										
DC	0.11	0.22**									
LL	0.46**	0.64**	0.28**								
LD	0.44**	0.41**	-0.23**	0.37**							
PL	0.45**	0.41**	-0.30**	0.35**	0.89**						
CW	0.42**	0.44**	-0.35**	0.32**	0.89**	0.91**					
FKW	0.39**	0.40**	-0.17*	0.35**	0.55**	0.57**	0.63**				
FC	0.38**	0.37**	-0.27**	0.30**	0.77**	0.76**	0.83**	0.65**			
DP	0.37**	0.31**	-0.45**	0.21**	0.81**	0.86**	0.92**	0.51**	0.70**		
CCI	0.37**	0.33**	-0.39**	0.26**	0.89**	0.91**	0.99**	0.61**	0.82**	0.93**	

** $P<0.001$, * $P<0.01$. Levels of signification

Carcass weight (CW), length of carcass (LC), depth of carcass (DC), length of hind leg (LL), carcass fat cover (FC), fat kidney weight (FKW), carcass compactness index (CCI), perimeter of leg (PL), dressing percentage (DP), depth of leg (LD). length and the leg perimeter (r = -0.39). They also found a negative correlation between width of carcass and other measurements taken on the carcass. Laville *et al.* (1996) reported lower correlations coefficients between carcass weight, length of leg and carcass length.

Table 1. Means, standard deviation (SD) and coefficient of variance (CV) of the variables measured on the carcass.

Parameters	Mean	SD	CV (%)	Minimum	Maximum
Age (month)	18.1	2.7	14.9	12.1	25.7
Live weight (kg)	499.7	113.5	22.7	350.0	828.0
Carcass weight (kg)	276.3	86.9	31.4	189.2	526.0
Length of carcass (cm)	132.9	5.1	3.8	119.0	147.0
Depth of carcass (cm)	39.6	2.2	5.5	35.0	47.0
Length of hind leg (cm)	84.3	2.8	3.4	78.0	92.0
Perimeter of leg (cm)	114.2	9.44	15.8	99.0	139.0
Depth of leg (cm)	26.7	4.2	8.3	20.0	37.0
Fat thickness (mm)	3.8	1.9	51.1	1.7	11.9
Weight of kidney fat (kg)	3.9	1.2	31.5	2.3	9.5
Dressing percentage (%)	54.4	4.5	8.4	48.1	64.9
Carcass compactness index (kg/cm)	2.1	0.1	29.8	1.5	3.7

Epley *et al.* (1970) reported positive correlation between carcass weight, weight of kidney fat (r = 0.63) and fat thickness (r = 0.61). These results were similar to those found in the present study for correlation between carcass weight and weight of kidney fat (r = 0.63). However, results reported by these authors were lower than those found in our study (r = 0.83) for correlation between carcass weight and fat thickness. Correlation between carcass weight, leg length and round depth (r = 0.74) reported by Abraham *et al.* (1968) were lower than those found in this study.

Correlation between carcass weight and length of carcass (r = 0.80) reported by these authors were higher than those found in our study (r = 0.44). Correlation between carcass weight and dressing percentage (r = 0.92) found in our study were higher than those (r = 0.43) reported by Wilson *et al.* (1964). However, these authors reported lower coefficient of correlations between carcass weight, fat cover (r = 0.22) and kidney fat percentage (r = 0.12) than those found in our study. Berry *et al.* (1973) found negative correlation coefficient between different carcasses varying in carcass length. Results reported by these authors are not in concordance with those found in the present study.

Principal component analysis (PCA): Results of the PCA of carcass measurements are given in Table 3. Two main PC in decreasing order were identified in this analysis. The component (CP1) explained 72.32% of the variability, whereas CP2 explained 15.25%. These two first components carry about 87.57% of the variance of the data.

Results in Table 3 showed high correlations between CP1, carcass weight (r = 0.97), thickness of the hind leg (r = 0 .95), perimeter of the hind leg (r = 0.94), carcass dressing percentage (r = 0.90), thickness of fat cover (r = 0.85) and carcass compactness Index (r = 0.96). Whereas, the chest depth of the carcass was negatively correlated with the first component (r = -0.29). The second component (CP2) had a high positive correlation with the carcass length (r = 0.75) and that of the hind leg (r = 0. 82).

Alberti *et al.* (2005) described principal component analysis for the carcass measurements similar to our results. These authors showed that the first component explained about 57.61%, while the second explained about 19.62% of the variance. The principal component analysis performed by Alberti *et al.* (2005) for carcass measurements mainly, for those related to the length of the carcass (r = 0.87) and that of the hind leg (r = 0.69), showed high correlation coefficients with the second principal component. These results were similar to those found in our study. Laville *et al.* (1996) performed carcass measurements on Charolais bulls slaughtered at 18 months age, recorded low correlation between the carcass weight and the length of the carcass (r = 0.08) and that of the hind leg (r = 0.34). These results are quiet similar to those found in our study where the correlation between the carcass weight and the length of the carcass was r = 0.26 and that of the length of the hind leg was r = 0.10. In another study, Alberti *et al.* (2008) performed a PCA of fifteen beef breeds and reported that the first component explained about 48.8% of carcass variability and was related to compactness index, dressing percentage and carcass weight. However, the second component explained 24.5% of variation and was related to fat percentage and kidney fat weight. These results are quite similar to those found in our study.

Table 3. Principal component loading.

Parameters	CP1	CP2	CP3
Age	0.47	0.37	-0.07
Carcass weight (kg)	0.97	-0.06	-0.04
Depth of leg (cm)	0.95	-0.03	0.06
Perimeter of leg (cm)	0.94	-0.04	0.03
Dressing percentage (%)	0.90	-0.18	-0.04
Fat thickness (mm)	0.85	-0.02	0.06
Weight of kidney fat (kg)	0.63	0.13	0.01
Carcass compactness index (kg/cm)	0.96	-0.16	0.01
Length of carcass (cm)	0.48	0.75	-0.43
Length of hind leg (cm)	0.39	0.82	0.38
Depth of carcass (cm)	-0.29	0.49	0.02
Eigenvalues	6.50	1.37	0.35
Proportion of variance (%)	72.32	15.25	3.97
Cumulative variance (%)	72.32	87.57	91.54

The eleven initial variables are described graphically (Fig.1). The coordinates of these variables are the correlations of variables with these components. Component 1 presented high positive correlations with the carcass weight, the depth and the perimeter of the hind leg, the dressing percentage, the fat thickness and the compactness index. Component 2 showed high correlations with the length of the carcass and the hind leg length. Principal component analysis identified two groups of variables. The PC1 was correlated with variables related to width and depth indicating the carcass conformation, whereas PC2 can be considered as an indicator of the carcass bone structure.

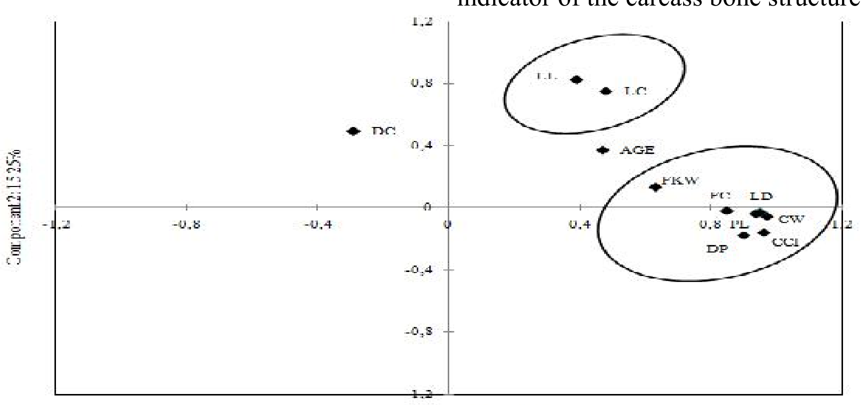

Fig.1. Carcass traits projection based on the two first components (PCs). Carcass weight (CW) ; length of carcass (LC) ; depth of carcass (DC) ; length of hind leg (LL) ; carcass fat cover (FC) ; fat kidney weight (FKW) ; carcass compactness index (CCI) ; perimeter of leg (PL) ; dressing percentage (DP); depth of leg (LD).

Cluster analysis: Cluster analysis upon the two components (Fig.2) revealed the identification of four classes of carcasses as follows:

- Cluster 1: bulls with a carcass weight between 180 kg and 230 kg, perimeter of the hind leg between 100 cm and 110 cm and a carcass length between 120 cm and 130cm. (1) low weight and small size carcasses.
- Cluster 2: bulls with a carcass weight between 231 kg and 300 kg, perimeter of the hind leg between 111 cm and 120 cm and a carcass length between 131 cm and 140cm. (2) average weight and large size carcasses.
- Cluster 3: bulls with a carcass weight between 301 kg and 400kg, perimeter of the hind leg between 121 cm and 130 cm and a carcass length between 120 cm and 130cm. (3) heavy weight and small size carcasses.
- Cluster 4: bulls with a carcass weight between 401 kg and 530kg, perimeter of the hind leg between 131 cm and 140 cm and a carcass length between 131 cm and 140cm. (4) heavy weight and large size carcasses.

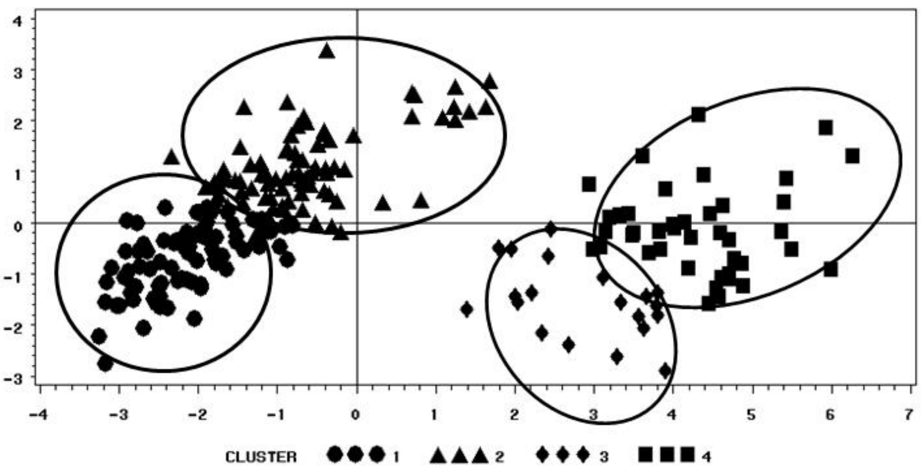

Fig.2. Projection of the four carcass groups identified upon the two principal components (PCs).

Table 4 summarizes the results of the measurements performed on the four different classes of carcasses identified through the cluster analysis on the basis of the two principal components identified in this study. These results showed that carcass weight, width and perimeter increase as far as we change from cluster 1 to cluster 4. Carcasses grouped in cluster 1 and 2 were mainly dairy breeds and had a weight range between 189 and 330 kg whereas those in cluster 3 and 4, beef type breeds had a weight range from 316 to 526 kg. Significant differences were also found between the four classes for the carcass weight, width, and the perimeter of the hind leg. The statistical analyses revealed significant differences for fat thickness, kidney fat weight and carcass compactness index between the four classes showing the highest values for carcasses classified in cluster 4. Furthermore, carcasses form cluster 4 compared to those classified in the three first clusters 1, 2 and 3 showed the higher values in terms of carcass weight (429 kg vs. 379 kg, 243 kg and 212 kg), perimeter of the hind leg (130 cm vs. 124 cm, 112 cm and 107 cm), and depth of the hind leg (33 cm vs. 32 cm, 26 cm and 23 cm). Tatum *et al.* (1988) showed also the same tendency for frame size and muscling score for carcasses having increasing carcass weight. Węglarz *et al.* (2010) reported that carcass weight and fat thickness increase simultaneously with the increase of conformation score. These results were similar to those found in our study mainly for clusters1and 2. Panea *et al.* (1999) reported that carcass parameters increase according to the carcass weight in Holstein bulls slaughtered at two different weights. They recorded higher values for carcass length and width of the hind leg for carcasses having higher weight. These finding were similar to those recorded in the present study showing that depth of the hind leg increased with the cluster 1 and 4. Results reported by Nichols *et al.* (1964) for the carcass dressing percentage showed that this parameter increased with increasing carcass weight and conformation score for Holstein bulls. These results reflect the trend in our study showing that the dressing percentage for the carcasses obtained from the Holstein bulls classified in the cluster 2 was higher than those recorded for the cluster 1 with the increase of the carcass weight. In contrast, McGee *et al.* (2007) reported that carcass length, length and width of the hind leg increased in Holstein and Charolais bulls slaughtered at distinct weights. Those results are similar to those recorded in our study for clusters 3 and 4, where carcass parameters were significantly different from those found in cluster 1 and 2.

Table 4. Means and standard errors of measurements by class of carcass.

Parameters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	s.e.	*P* value
Observations (n)	86	83	20	41	-	-
Age (month)	16^a	19^b	18^c	20^d	0.17	<0.0001
Carcass weight (kg)	212^a	243^b	379^c	429^d	7.48	<0.0001
Length of carcass (cm)	129^a	136^b	130^a	137^b	0.33	<0.0001
Depth of carcass (cm)	39^a	41^b	38^c	38^c	0.14	<0.0001
Length of hind leg (cm)	82^a	86^b	83^c	86^b	0.18	<0.0001
Depth of leg (cm)	23^a	26^b	32^c	33^d	0.27	<0.0001
Perimeter of leg (cm)	107^a	112^b	124^c	130^d	0.62	<0.0001
Weight of kidney fat (kg)	3.3^a	3.9^b	4.1^b	5.6^c	0.08	<0.0001
Fat thickness (mm)	2.7^a	3.2^b	4.9^c	7.1^d	0.13	<0.0001
Dressing percentage (%)	51^a	53^b	61^c	61^c	0.30	<0.0001
Carcass compactness index (kg/cm)	1.6^a	1.7^b	2.9^c	3.1^d	0.04	<0.0001

^{a,b,c,d} Row means with different superscripts differ significantly at $P < 0.05$.
s.e: standard error.

Tissue composition: Table 5 shows the tissue composition of the sixth rib dissection in terms of lean meat, fat, bone and others. Lean meat and bone percentage varied significantly between four clusters. Cuts from cluster three and four had higher lean meat content than those from the other clusters, with an average difference ranging from 3% to 11%. Lean meat content in the carcass increased significantly from cluster 1 to 4, whereas, bone percentage decreased. Carcasses form different clusters differed also considerably with respects to fat content.

Table 5. Tissue composition of the sixth rib cuts.

Parameters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	s.e.	*P* value
Observations (n)	33	25	16	30	-	-
Lean meat (%)	65^a	68^b	72^c	76^d	7.48	<0.0001
Fat (%)	8^a	9^a	12^b	11^b	0.33	<0.0001
Bone (%)	24^a	20^b	14^c	11^d	0.14	<0.0001
Tendons (%)	3	3	2	2	0.18	<0.0001
Lean meat/bone ratio	2.8^a	3.4^b	5.2^c	6.9^d	0.19	<0.0001

^{a,b,c,d} Row means with different superscripts differ significantly at $P < 0.05$.
s.e: standard error.

Dolezal *et al.* (1993), studying carcass composition of beef cattle carcasses having three different frames sizes (small, medium and large), showed significant differences in bone percentage. These results are similar to those found in our study. Tatum *et al.* (1988) reported higher values for lean meat with the increase of conformation score of the carcass. They also reported an increase of the muscle to bone ratio with better conformation score of the carcass. This tendency is similar to the one found in our study, where the muscle to bone ratio increased from 2.8 to 6.9 respectively for carcasses in cluster 1 and 4. Bonaïti *et al.* (1988) reported lean muscle percentage about 75.2% and 71.9% respectively for Limousin and Charolais breeds having 18 months old. Fat percentages were equal to 12% and 14% for both breeds. Those results are similar to those found in our study for cluster 3 and 4. Clarke *et al.* (2009) reported higher lean muscle percentage in Limousin and Charolais carcasses compared to Holstein breeds. However, bone and fat percentages were higher in Holstein breeds. Those results were similar to those found in cluster 1and 2 compared to carcasses classified in cluster 3 and 4. Martinsson & Olsson (1993) showed an increase in fat content in carcasses of Friesian bulls with an increase in age. Lean muscle percentage decreased as far as animal get aged. The results reported by these authors are also similar to those found in the present study for fat content in Holstein carcasses grouped in cluster 1 and 2.

Conclusion: This study used principal component analysis followed by cluster analysis to categorize beef cattle carcasses in Tunisia into four groups to establish a carcass grading system. Categorization of morphometric measurements provides producers and butchers with a simple system that makes transactions more transparent and reflects the values of carcasses in Tunisian slaughterhouses and meat processing plants. Carcass weight, perimeter of the hind leg and the length of the carcass can be used as the main measurements to establish a grading grid. In practice, a technical guide could be developed showing figures of the different category characteristics which include a combination of carcass weight (light or heavy), length of the carcass (large or small), and perimeter of the hind leg (high and low) . Fat thickness and carcass maturity could be also included in the grading system. This will be used as a template by professionals operating at the level of the meat processing plants and slaughterhouses and ease the sale transactions of carcasses for butchers and meat retailers.

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