Vol 13 No 1, p 67-72

ASSESSMENT OF BODY CONDITION AND BODY COMPOSITION IN CAMEL BY BARYMETRIC MEASUREMENTS

Asma Kamili[1], M Bengoumi[1] and B Faye[2*]

[1] Department of Pharmacy, Toxicology and Biochemistry, P.O. Box 6202. I.A.V. Hassan II, Rabat, Morocco

[2] CIRAD-EMVT, Campus International de Baillarguet, TA 30/A 34398 Montpellier, France

ABSTRACT

The present study aimed to assess the live weight, carcass weight and the importance of fat storage in camel by barymetric measurement before and after slaughtering. A total of 61 camels aged between 6 months and 15 years were measured at the abattoir of Dakhla in south of Morocco. The barymetric measures were achieved before slaughtering. After the death of the animals, the hump volume was estimated by using Archimedes' principle. The hump length and the height were good indicators of the carcass weight (r= 0.73 and r = 0.78, respectively) and of the live weight (r = 0.54 and r = 0.53, respectively). Neck perimeter and thigh perimeter were good predictors of the carcass weight. The live weight and carcass weight could be assessed by the following equations: (i) Carcass weight (kg) = 1.21 x (Hump height (cm) +neck perimeter (cm)) – 17.49; (ii)Live weight (kg) = 4.06 x Age (year) + 3.05 x neck perimeter (cm) + 3.38 x thigh perimeter (cm) + 1.38 x hump length (cm) – 191; with 86 and 94% of the explained variance, respectively. Hump volume, length and height of the hump were good indicators of the adiposity of camel (correlations coefficient of 0.80, 0.70 and 0.60, respectively with the total fat storage. The hump represented 80% of the fat stored while the fat around kidney and mesentery represented 15 and 5%, respectively. The multivariate analysis allowed identifying three types of body condition (live measures) and body composition (post-mortem measures).

Keywords : body composition, body condition, dromedary camel, fat reserve

The camel is able to be adapted to extreme conditions of arid lands and can take advantage in harsh places from Africa or Asia. The hump which is very characteristic of the species is one element of this adaptation. It represents the physiological management of the fat storage by the animal all along the cycle stocking/destocking (Faye *et al*, 2001b).

In camel, the fat is concentrated in the hump that allows heat dissipation on the other part of the body (Yagil, 1985; Chilliard, 1989). However, the hump is not sufficient to assess the body condition. In a preliminary study the hump weight was correlated with its length and height. A formula to estimate the hump volume from its length and width was established (Faye *et al,* 2002).

In the present study, the distribution of body fat was assessed from barymetric and weight parameters. Also, the relations between body condition on living animal, post-mortem body composition and fat storage or between hump volume, hump weight, fat storage and live weight were studied.

Materials and Methods

In present study 61 maghrebi camels (12 males and 49 females) at different ages were weighed (on a balance with ± 1 kg precision) and measured before and after their slaughtering at the abattoir from Dakhla in Saharan province of Morocco. For each animal, data on physiological stage, type of production, drinking status, feeding status and origin of the herd were recorded.

On the standing or sitting animal, according its docility, the body measurements were taken with a meter-ribbon (Fig 1). Neck perimeter (TE) comprised neck measurement at the level of cervical vertebra C_3 and C_4. The heart girth (TP) measures corresponded to the circumference of thorax by passing the meter-ribbon under the sternal cushion and in front of the hump. The abdomen perimeter (TA) measures corresponded to the abdomen circumference passing by the top of the hump. The thigh perimeter (PC) measures corresponded to the circumference at the middle of the thigh. The hump size included the length (LB) measured between the cranial and caudal

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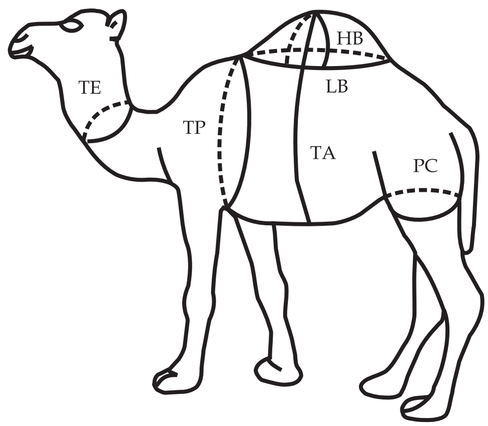

Fig 1. Body measurements of the living camels

limit passing by the base of the hump and the height (HB) measured between the base (costal limit) and the top of the hump. It was measured between the cranial and caudal limit passing by the base of the hump.

The camels were weighed individually at the entry of the slaughterhouse with a balance at ± 1kg precision.

Body composition and measurements on slaughtered animals

After slaughtering and separation of the hump from the carcass, the length and height were measured on the separated hump in order to verify the precision of the former measurements. Then, the volume was estimated using Archimedes' principle. For this the hump was put in plastic bag and absorbed in graduated container full of water. The operation finished when the water stopped pouring. After withdrawing of the hump, the lost water corresponding to the hump volume was measured thanks to graduation of the container.

The fat around the kidney and in mesentery was weighed by a small scale with ± 250 g accuracy. Other organs (liver, heart, lungs, skin, head, neck, empty digestive tract and limbs) and carcass were weighed with the same scale.

Statistical analysis

Data were catching on Excell software, converted in data base DBF-III, then treated with STAT-ITCF software. By multiple linear regression the relationships between 24 variables (different measurements) were determined. The correlation coefficients were significant when the value of r was above 0.25 ($p<0.05$) or 0.32 ($p<0.01$) for 60 degrees of freedom ($n=61$). To identify the variables in opposition and determine the correlated variables into a multivariate analysis, the Principal Components Analysis (PCA) was achieved. The Ascending Hierarchical Classification (AHC) and Factorial Discriminating Analysis (FDA) allowed grouping the animals into homogenous classes according to similarity criteria (Lebart and Morineau, 1984). The classes obtained with measurements on live animals expressed the body condition. The classes obtained with measurements in post-mortem expressed the body composition.

Results

General measurements

Weight

The studied camel population was young (mean: 5 ± 4 years) with 310 ± 100 kg live weight and 137 ± 35 kg carcass weight on average. Dressing percentage was 46% on an average.

Hump size

The hump measurements (length, height volume, weight) were highly variables. The differences between measurements, before and after slaughtering (on an average 42 *vs* 46 cm for length and 23 *vs* 22 cm for height) were not significant ($p>0.05$). However, the measurements on the living animals must be done by trained operators.

The mean hump weight (PB) was 7.0 ± 8.0 kg with extreme values between 0.5 and 40 kg. The hump volume (VB) was 8.0 ± 9.0 l on an average.

Fat storage

The hump is the main fat storage organ in camel. It represented in the present study 79.8% of the total measured fat (sum of the hump, mesentery and perirenal fat weight). The perirenal fat weight was 0.70 ± 0.47 kg and the mesenteric fat weight was 0.30 ± 0.20 kg. It represented 15 and 5% of the total fat (table 1).

Table 1. Weight and proportions of fat storage measured in camel.

	Hump weight (kg)	%	Mesenteric fat weight (kg)	%	Perirenal fat weight (kg)	%
Mean	7.0	79.8	0.30	5.26	0.70	15.0
SD	8.0	14.2	0.20	5.37	0.47	12.3
Maximum	40.0	98.2	1.00	23.1	2.00	50.0
Minimum	0.50	30.8	0.00	0.00	0.00	0.00

Body composition

The weight of the internal organs (liver, kidney, heart, lungs) represented 10% of the live weight.

The digestive tract, the skin and limbs represented 17.5% of the live weight. The fat storage represented 2% of the live weight. The remaining part was of the digestive tract contents.

The organs such as liver and kidney represented 2.7% of the total live weight (2% for liver and 0.7% for kidney). The kidney weight was not very variable (around 2 kg) and appeared as independent of the live weight, contrarily, the liver weight was linked to the weight of the animal. Indeed, the live weight was significantly correlated with the liver weight (r = 0.43).

Relationships between the measurements

Hump parameters

The weight and the volume of the hump were obviously highly correlated (r=0.89). The hump volume was also correlated as well as for length (r=0.81) and height (r=0.78) before slaughtering than after (0.82 and 0.79, respectively). The weight was little bit less correlated but still highly significantly to length and height before slaughtering (0.76 and 0.72) than after (0.81 and 0.77, respectively). As the whole, the hump volume was better correlated to the measurements than the hump weight.

The hump volume could be assessed by the following formula which expressed 85% of the variance:

Hump volume (l) = 0.24 Length (cm) + 0.27 Height (cm) – 8.63

The t student test showed no significant differences in the hump measures before and after the slaughtering.

Correlations of live and carcass weight with body measurements

The live weight was correlated with the carcass weight (0.63). Age, neck perimeter and thigh perimeter were the best indicators of the live weight of the animal. Correlations were 0.64, 0.62 and 0.62, respectively (table 2). Concerning the hump, live weight was significantly correlated to the length (r=0.54, the height (0.53), the hump weight (0.45) and the hump volume (0.47). The following equation expressed 86% of the variance:

Live weight (kg) = 4.06 x Age (year) + 3.05 x neck perimeter (cm) + 3.38 x thigh perimeter (cm) +1.38 x hump length (cm) – 191

Residual SD = 60.3 kg

The carcass weight was highly correlated to neck perimeter (0.79), height and length of the hump (0.78 and 0.73 respectively) and in a less extend with life weight (0.63) due to differences in the drinking status of the animals. The relationships with the thigh perimeter (0.26) and abdomen perimeter (0.36) were lower but significant ($p < 0.05$). The following equation was determined and explained 94% of the variance:

Carcass weight (kg) = 1.21 x (hump height (cm) + neck perimeter (cm) – 17.50

Residual SD = 6.91 kg

These two models achieved the conditions of normality and independence. To take in account the heterogeneity of the population, the PCA was achieved showing that the two main factors of the analysis expressed 64% of the variance. The correlation circle (F1, F2) showed clearly two groups of variables. The first group was composed of hump parameters (weight, volume, length and

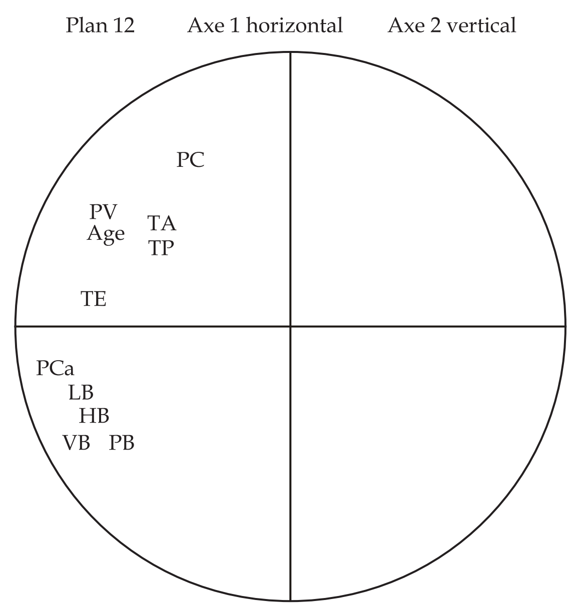

Fig 2. Correlation circle (F1.F2) of parameters determining the body condition in camel (PCa: carcass weight; PV: live weight)

Table 2. Correlation coefficient (r) between live weight, carcass weight and body measurements in camel.

Correlation Coefficient	age	Live weight (kg)	Hump length (cm)	Hump height (cm)	Neck perimeter (cm)	Heart girth (cm)	Thigh perimeter (cm)	Abdomen perimeter (cm)	Carcass weight (kg)
Carcass weight (kg)	0.60	0.63	0.73	0.78	0.79	0.35	0.26	0.36	1.00
Live weight (kg)	0.64	1.00	0.54	0.53	0.62	0.34	0.62	0.38	0.63

height) and the carcass weight positively and highly correlated between them. Live weight correlated to conformation parameters (thigh, abdomen and thorax perimeters) composed the second group. The neck perimeter was between those two groups (Fig 2). Those results were confirmed by multiple linear regression and the projection of the individuals on the factorial plan (F1, F2): the first factor of PCA opposed the young, light camels with a small hump, narrow neck and thigh perimeters to old camels with bigger hump, abdomen perimeter and thigh circumference. The medium size animals were represented on the factor 2.

This representation was confirmed by the classification (AHC). Three types of animals were identified explaining 73% of the variance. The discriminating analysis allowed separating these 3 groups of body condition with a high discriminating power i.e. 93% of well classified (table 3).

Table 3. Mean values for the discriminating groups of body measurements parameters.

Variables	PV (kg)	LB (cm)	HB (cm)	TE (cm)	TP (cm)	PC (cm)	TA (cm)	VB (1)	PB (kg)
Low body condition	223	34.0	18.5	52.3	172	67.0	203	3.80	3.20
Medium body condition	352	47.6	26.2	63.4	195	76.1	216	11.3	8.80
High body condition	464	52.6	28.0	64.0	188	86.0	228	13.6	12.10
Mean	310	41.9	22.8	58.1	183	73.2	212	8.00	6.70

Correlations of live weight with body composition (BCp)

The live weight was better correlated with the forelimbs (0.74) than with the carcass weight. According to the multivariate analysis (discriminant analysis), 3 groups of animals were identified according to their body composition parameters (table 4) with a good discriminating power (74% well classed animals).

Table 4. Mean values for the discriminating groups of body composition weight.

Variables	PV (kg)	PCa (kg)	liver (kg)	heart (kg)v	kidney (kg)	lung (kg)	Digestive tract (kg)	limbs (kg)	skin (kg)
BCp 1	223	65.9	4.60	1.30	1.80	2.30	11.8	10.3	19.3
BCp 2	355	89.1	7.30	1.90	2.30	4.20	14.4	14.4	30.4
BCp 3	471	103	7.30	2.10	2.30	3.50	15.1	12.9	25.6
Mean	310	80.2	6.00	1.60	2.10	3.00	13.4	11.9	23.3

Except for three camels in the whole population, the groups obtained with body composition were similar to body condition groups. So, the body condition assessed with live body measurements was a good indicator of the body composition after slaughtering.

Interrelationships between fat storage in hump, mesentery and around kidney

The hump weight was significantly correlated to the mesentery weight (0.65) better than to fat around kidney (0.41). Correlation between mesentery and perirenal fat storage was intermediate (0.49). Among the fat storage, only hump was significantly correlated to live weight (0.30) and carcass weight (0.30).

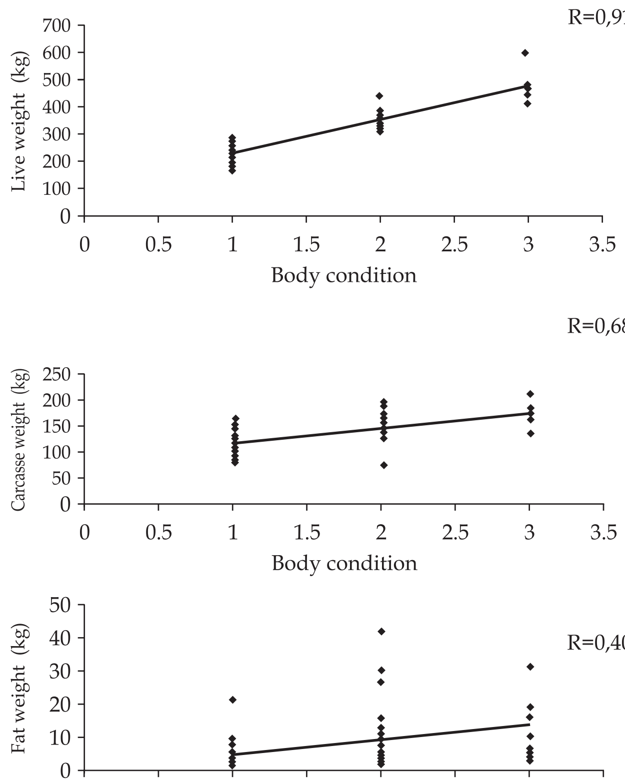

Fig 3. Relation between body condition groups, live weight, carcass weight and fat weight.

The whole fat storage weight in these 3 organs was 7.65 ± 8.68 kg with extreme values between 0.750 kg and 42 kg, i.e. 2.31± 2.27 % of the live weight (0.4 to 10.5 % as extreme values). The body condition was highly correlated to live weight, carcass weight and to the fat weight but with a lower coefficient (Fig 3).

Discussion

As the population was heterogeneous, the effect of age, sex and physiological status could not be taken into account. Moreover, the exact age of the animals at the slaughterhouse was not easily determined. The hump was a good predictor of the carcass weight, and the body measurements were a better predictor of the carcass weight. Faye *et al* (2002) reported good correlations between hump measurements (length and height), thigh perimeter and carcass weight. Thigh perimeter and neck perimeter were good predictors of live weight which was linked to the age of the animal. The age and the sex were more responsible of the skeletal development and the body condition was largely dependent of the maintenance status. So, the increase of those parameters means a significant bone-muscle growth.

The thigh perimeter indicating both the growth of fat and muscle was the indicator used by the butchers in many countries in accordance to Faye *et al* (2002). It was a better indicator of the hump size to assess the carcass weight. This observation is not clearly confirmed in the present study where the carcass weight is better correlated with neck perimeter and hump measurements.

The correlations between live weight and body composition (especially organs of cardiorespiratory system) are common. There is a relation between the size of the animal and respiratory function. In cattle, allometric algorithm is available for long time (Torrance, 1998).

The hump is the most important fat reserve in camel and represents 80% of the whole fat stored (except in muscle, sternal pad, coastal part, shoulder as mentioned by Ollier *et al* (1995). The general repartition of the fat in camel is different than in cow (Robelin, 1986), sheep (Ali and Khamldi, 1987) and goat (Mohrand-Fehr and Brauca, 1987). It is a form of mobilisable energy to cover maintenance and production requirements (Bengoumi, 1992). With a mean weight of 7 kg and extreme values of 0.5 to 40 kg, our results are similar to those of Mirgani (1977) and non-published results from Tunisia (Faye *et al*, 2002). Chilliard (1989) reported that hump weight could reach 100 kg in very fat animal, but the main variations are between 0 and 39 kg. The hump weight depends of the nutritional and physiological status (Wilson, 1978), but the variations in the size are more concerned by individual change than for comparison between animals (Faye *et al*, 2002).

In our study, the fat storage represented 2.4% of the live weight and 5% of the carcass weight whereas in cattle with medium body condition score, fat is 20% of the carcass. According to unpublished results from Tunisia, the fat represents 8% of the carcass (Faye *et al*, 2002).

According to our results, one point of body condition score (BCS) increase corresponded to 103.2 kg of live weight and 84.5 kg of carcass weight. In cattle, one point of BCS increase corresponds to 38 kg of lipids and 65 kg of live weight (Chilliard, 1989).

The relationships between hump weight and perirenal fat were already observed by Faye *et al* (2002). But the correlation between the hump weight and the mesentery weight was slightly higher. Kadim *et al* (2002) shown that composition of lipids from the hump and mesentery was identical. According to the measurement of the adipocyte size (Faye *et al*, 2002; Bengoumi *et al*, 2005), it seems that the fat storage begins in perirenal fat before the hump.

Conclusion

Live and carcass weight can be predicted easily by body measurements on the live animal at a good precision with no consideration of the age: neck perimeter, thigh perimeter, length and height of the hump are the mean retained parameters. The hump volume (better than the weight) is a good predictor of the individual fat condition. The present elements are available to contribute at the definition of a body condition score in camel (Faye *et al,* 2001a). Indeed, the groups of body condition identified in the present study could correspond to the body condition score set up in the previous study.

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