Emir. J. Food Agric. 2012. 24 (3): 272-280
http://ejfa.info/

ANIMAL SCIENCE

Phenotypic classification of Saudi Arabian camel (*Camelus dromedarius*) by their body measurements

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Abstract

In order to identify homogeneous groups of camels according to their conformation, 212 camels (155 females and 57 males) from 9 regions of the Kingdom of Saudi Arabia, and belonging to 12 different camel breed or types were measured. The body measurements included the length of the head, of the neck, of the udder and of the teat, the height at the withers, and the circumference of the neck, of the thigh and at girth. The 12 breeds were compared according to their mean body measurements and the groups with similar conformation were identified by Automatic Hierarchical Classification on Ward distance. Finally, 4 types of female camel conformation were identified: small size breed from mountains and Red Sea coast, big size camel from desert areas, and 2 breeds, Zargeh with small size but with wide chest and neck, and Asail (racing camel) with very thin neck and leg and poorly developed udder. Six groups of males are identified also but with a different distribution. This classification is close to the typology based on the ecosystem distribution of camel breeds in Saudi Arabia.

Key words: Body measurements, Camel breed, Classification, Dromedary camel.

Introduction

The total population of dromedary is estimated to be around 1.6 million camels within the Arabian Peninsula, about 53% found in Saudi Arabia (source: FAO statistics, 2011). However, there is an important gap between the official number of camel heads according to FAO statistics (280,000 in 2009) and the national estimation published by the Ministry of Agriculture in Saudi Arabia (830,000 heads). Based on this last estimation, the camel population is 51% of the total tropical livestock unit (TLU) in the country. The camel population is increasing since the year 1961, passing from 80,000 to 280,000 in 2009; i.e. approximately a growth of 5.2%/year. The importance of camel in Saudi Arabia is clearly underlined by these data (Gaili et al., 2000).

However, during the same time the milk and meat productivity increased but in similar proportion: 5.4%/year for milk production and 6.4%/year for meat production (Faye and Bonnet, 2012). This increase of milk and meat productivity in camel was mainly linked to the population growth. Regarding the higher growth in meat production, it was rather due to the increase of slaughtering rate than to the growth of meat productivity. Indeed, the mean carcass weight was the same in 2009 compared to 1961 (224 kg) and the slaughtering rate increased by 6.62%/year. The dairy productivity did not change also for the last 48 years and the increase of dairy production was linked to the increase of proportion in dairy animals passing from 62 to 69%; i.e. a growth by 5.53% per year (Faye and Bonnet, 2012). Thus, the increase in available production was mainly mechanical and due to the population growth.

Elsewhere, the Arabian Peninsula is probably one of the main area where the dromedary camel was domesticated 5000 to 6000 years ago (Uerpman and Uerpman, 2002), and the place where the camel biodiversity is one of the most important in the world. Formerly, a dozen of "breeds" are described (Faye et al., 2011) mainly based on their coat color.

However, their differences on other parameters as their general conformation were not clearly described. There is no clear classification of Saudi Arabia camel populations with ecological, morphological and utilities criteria generally mixed (Almathen et al., 2012). Yet, it would be an

Received 03 December 2011; Revised 24 February 2012; Accepted 27 February 2012

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important step to propose control of performances for further potential selection programs in order to contribute for the improvement of camel productivity. Thus, the present study aims to classify the described camel breed of Saudi Arabia on the base of their body measurements only in order to identify some groups with similar conformation.

Materials and Methods

The survey

As the whole, 152 camel owners were visited. They lived in 9 regions of the kingdom (Al-jouf, Ar'ar, Tabuk, Tabarjal, Riyadh, Qassim, Hail, Jazan, Al-Bahah). They were selected on the basis of the variability in the breed composition of their camel farms. In each farm, a questionnaire was applied and body measurements were achieved: all female and male camels had between 5 and 10 years old (adults having finished their growth), and they were regarded by their owner as the more characteristic specimens for a given breed. By this participative approach, the total size of the sample could be limited. Finally, the data involving 212 camels (155 female and 57 males) belonging to 12 different camel breeds (or types) were collected. As the description of these different camels are not yet clear, the terms "breed" or "types" will be used indistinctly.

The measurements

The measurements were achieved on standing animals with a meter-ribbon and reported in cm. The following distances were collected: (i) the length of the head from nose to occipital (LH), (ii) the length of the neck (lower part) from base of head to the chest (LN), (iii) the circumference of the neck at the middle of the neck (CN), (iv) the height at the withers (HW), (v) the girth circumference in front of the hump (GC) and the thigh circumference at the middle of the thigh (TC), then in females (vi) the length of the left front teat (LT) and finally (vii) the length of the udder from the front to hind attach (LU).

The statistical analysis

The statistical analysis included three steps:

(i) Each breed was described by the mean (± S.D) of the different reported measurements and their within variability. To compare the different breeds, a variance analysis was applied in order to identify the significant differences for each measurement between breeds.

(ii) The correlations between the different measurements were assessed by calculating the correlation coefficient of Pearson for a given sex.

(iii) In a third step, a table including the 12 identified breeds (in row) and the different mean values of body measurements (in column –see table 1) was analyzed by automatic clustering. The principle of the method of automatic classification (or clustering) was based on the identification of homogeneous groups of individuals (clusters) in the population (here, camel breed). Two camel breeds belonging to the same group were somehow close to each other (similar means of body measurements). At reverse, two camel breeds belonging to different groups are somehow far from each other (they have significant different body measurements). The classification consists to build a partition of the population into homogenous clusters (having low within variability), different one from other (having high between variability). Each retained cluster, identified by the convenient cutting of a dendrogram (graphic expressing the dissimilarity between clusters or classes) would represent a "type" or a "cluster". The convenience of the cutting was estimated when the gain in between-cluster variance is not significant. The retained clustering is expressed by the total between-cluster variance explained by the model. The interpretation of the types was achieved by analyzing the contribution of the different variables to the class. Only variables with significant contribution (assessed by Chi square test) at $P > 0.05$ were retained for the final interpretation (Jain et al., 1999).

The statistical analyses were applied separately on females and males and the software XLSTAT (Addinsoft ©) was used.

Results

Succinct individual description of the camel breeds (Plate 1)

Hadhana breed is a yellowish to red coat color camel with a fine head, flat forehead, thin neck, narrow feet and medium size legs. He has a round and symmetric hump and no long hair on its body. It is mainly encountered in the hills around Al-Baha town in a limited area.

Awadi breed is a camel from southern part of the Kingdom with red to white coat color. A small head with a slight forehead, short and thin neck, small udder, pilosity in ears, head and neck, narrow feet and round hump are the main characteristics of the breed.

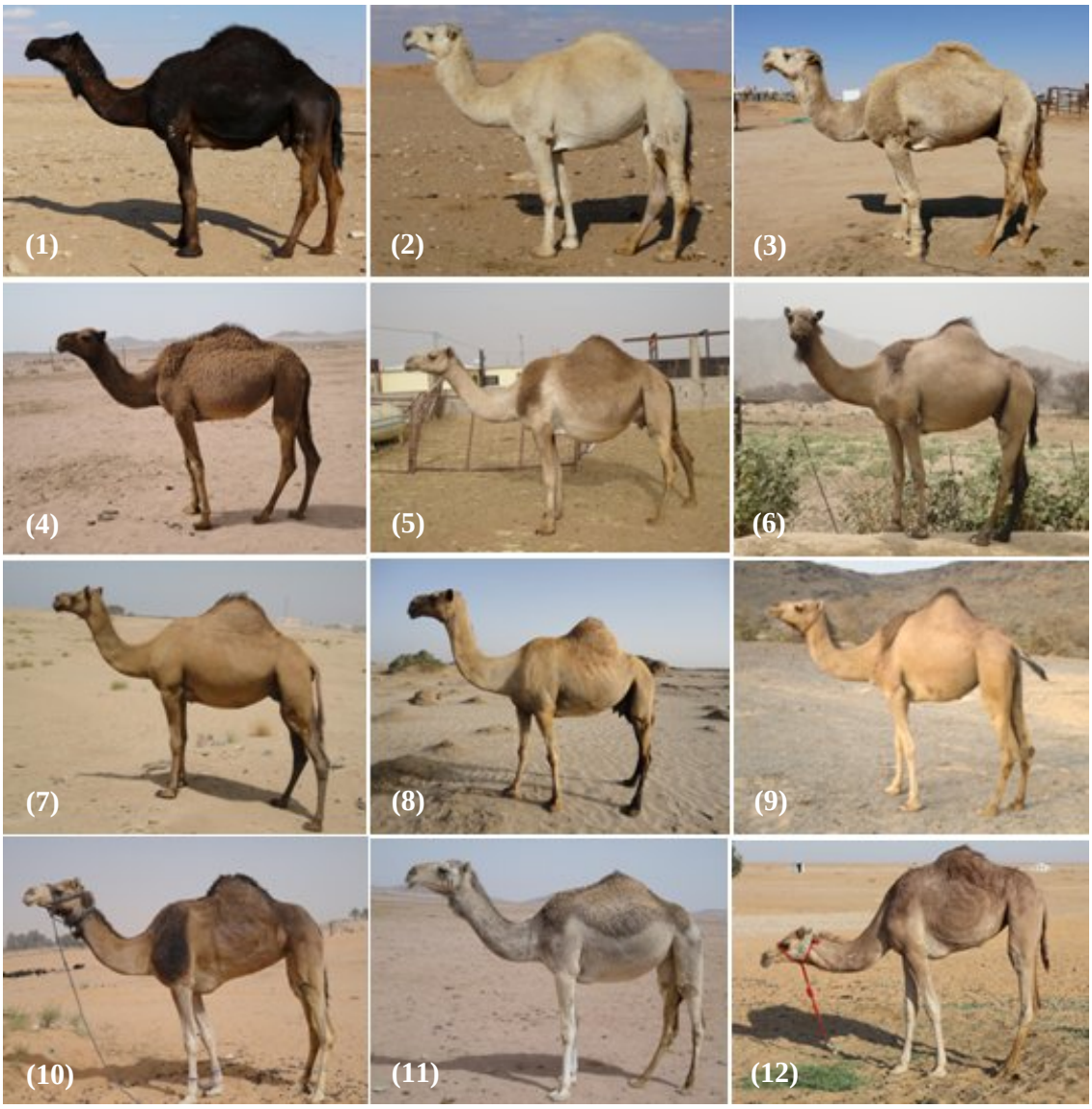

Plate 1. Camel breeds phenotypes photos from Saudi Arabia. (1) Majaheem (2) Waddah (3) Homor (4) Sofor (5) Shaele (6) Aouadi (7) Saheli (8) Awrk (9) Hadhana (10) Asail (11) Zargeh (12) Shageh.

Asail is a racing camel characterized by a fine head with flat forehead, pointed ears, very narrow feet and long legs, round hump in the hind of the back, small but balanced udder with very small teats. Its yellow to brown coat color has short hairs.

Awrk (Awarik) camel has a clear coat color, almost white, with short hair. It differs from Saheli breed by a more developed udder, medium neck circumference, pointed ears and its hump rather at the hind of the back. It is widely distributed in Jazan region. Its milk production is moderate.

Homor (or Hamrah) camel is a medium size dairy breed with a characteristic clear brown coat color. Its forehead is slightly marked in male and the ears are pointed with low pilosity. It is distributed in small number all over the country, but more common in the northern part.

Majaheem (also named Malah) is a characteristic black coat camel originated from north-east part of the country. A pointed hump, placed in the middle of the back, long hair covering all the body, long legs, wide feet, well developed udder are its main characteristics. It is one of the best dairy producers of the Kingdom.

Saheli, a typical camel living all along the Red Sea coast, has a characteristic red coat color, a small head with a pronounced forehead (even in

female), a small and thin neck, a small udder, round ears without hairs, narrow feet and round hump.

Shaele breed is a medium size camel and has a grey coat color going sometimes to brown-red especially in male, pointed ears, narrow feet, short legs and well symmetric hump. It is a common type in South-eastern part of the Kingdom.

Shageh is a small-head camel with short and thick neck, narrow chest but developed udder. It is close to Zargeh breed but its coat is greyer. It is more common in the southern part of the Kingdom.

Sofor (or Safrah) has a dark brown coat color with medium size, long head and neck, well developed udder, wide chest and long legs. The ears are pointed and the feet are large. Its body is widely covered with long hair. It is distributed in same area than Homor camel. It well resists to the climatic constraints of the desert.

Waddah (or Maghatir) has a white coat color, sometimes almost yellow. The characteristics are pointed ears with low pilosity, long legs and well developed hump. The male have a developed forehead and long penis case.

Zargeh, a southern camel, has a blue-grey coat color with long hair on the head, the neck, the shoulder and the hump. It has small head with short neck and flat forehead, pointed ears, small udder, unbalanced teats, a wide chest on short legs. The hump could be pointed and placed in hind part of the back. Sometimes, the coat color on shoulder and on the back is darker.

The mean values for females (Table 1)

The ranges for the individual measurements were 31-60 cm for the length of the head, 75-114 cm for the length of the neck, 57-111 cm for the neck circumference, 158-272 cm of the height, 102-274 cm for the girth circumference, and 60-110 cm for the thigh circumference. The udder length range was 10 to 50 cm and the teat length was 1 to 26 cm.

Table 1. Mean body measurements of 12 types or breeds of female camel in Saudi Arabia (in cm). ^{a,b,c,d} Means within column with different superscript differ ($P < 0.05$).

Breed	Lhead	Lneck	cNeck	Lteat	Ludder	Height	GirthC	ThighC
Hadhana	42.1^{b}	87.8^{d}	74.8^{d}	4.2^{b}	17.0^{b}	173.0^{c}	$180.5^{a.b}$	73.3^{c}
Aouadi	42.4^{b}	$97.6^{c.d}$	$79.3^{b.c.d}$	4.7^{b}	$15.7^{b.c}$	174.3^{c}	$191.3^{a.b}$	83.6^{b}
Asail	42.3^{b}	$94.3^{c.d}$	$86.3^{a.b}$	2.0^{b}	6.3^{c}	185.8^{c}	$199.3^{a.b}$	$78.3^{b.c}$
Awrc	41.5^{b}	$92.0^{c.d}$	$88.8^{a.b}$	4.6^{b}	$18.5^{a.b}$	199.3^{a}	$201.0^{a.b}$	$88.8^{a.b}$
Homor	46.5^{a}	$107.1^{a.b}$	$83.9^{a.b}$	4.7^{b}	25.6^{a}	186.7^{c}	217.3^{a}	93.1^{a}
Majaheem	46.9^{a}	110.7^{a}	89.4^{a}	6.8^{a}	25.0^{a}	$192.2^{a.b}$	219.2^{a}	94.9^{a}
Saheli	42.8^{b}	$96.2^{c.d}$	$86.4^{a.b}$	$5.1^{a.b}$	16.7^{b}	176.0^{c}	$195.9^{a.b}$	84.3^{b}
Shaele	46.9^{a}	$104.5^{a.b}$	$83.0^{a.b.c}$	4.1^{b}	24.8^{a}	$187.0^{b.c}$	213.5^{a}	86.9^{b}
Shageh	39.3^{b}	$92.3^{c.d}$	92.0^{a}	$5.2^{a.b}$	17.0^{b}	182.7^{c}	$180.7^{a.b}$	$90.3^{a.b}$
Sofor	48.1^{a}	$98.7^{b.c}$	$81.0^{a.b.c}$	4.3^{b}	$22.7^{a.b}$	185.3^{c}	220.9^{a}	85.3^{b}
Waddah	47.4^{a}	108.6^{a}	$79.0^{c.d}$	4.8^{b}	25.4^{a}	186.7^{c}	221.8^{a}	93.0^{a}
Zargah	40.5^{b}	87.0^{d}	91.0^{a}	4.5^{b}	$22.0^{a.b}$	185.0^{c}	222.0^{a}	86.5^{b}

The length of the head was significantly higher in Homor, Majaheem, Shaele, Sofor and Waddah breed. The length of the neck was higher in Majahee, Homor and Waddah and the lower significant values were observed on Hadhana and Zargeh breed. Majaheem, Shageh and Zargah had a significant higher neck circumference than Hadhana, Awadi and Waddah. The higher breeds were Majaheem and Awrk. The shorter were Hadhana, Awadi and Saheli. Regarding girth circumference, there was a high significant difference between Zargah, Waddah, Sofor, Majaheem and Homor in one hand, and Hadhana in another hand. Waddah, Majaheem and Homor had a high thigh circumference reverse to Hadhana and Asail. The length of the udder was quite more important for the breeds Shaele, Waddah, Majaheem and Homor and quite smaller in Asail. The length of the teat was quite higher in Majaheem attesting its dairy vocation. Asail had also very short teat.

The mean values for males (Table 2)

For the different body measurements, the values range were 41-59 cm (LH), 85-152 cm (LN), 55-119 cm (CN), 113-226 cm (HW), 134-249 cm (HG) and 73-123 cm (TC) showing a higher homogeneity than for females.

In male, there was no significant difference between breeds for the head length. The neck was significantly longer in Majaheem, Homor, Wadda and Shageh, reverse to Asail and Hadhana characterized by a shorter neck. The highest neck

circumferences were observed on Majaheem, Wadda, Saheli and Shageh while no significant difference was observed for height.

The girth circumference was also higher in Majaheem, Waddah, Homor and Sofor, but Shageh and Saheli were in the same group. The lowest measurement was reported on Awadi. The thigh circumference was highest in the same breeds than female, but also in Shageh. Asail breed has the finest thigh.

Table 2. Mean body measurements of 10 types or breeds of male camel in Saudi Arabia (in cm). [a,b,c,d] Means within column with different superscript differ (P < 0.05).

Breed	Lhead	Lneck	Cneck	Height	GirthC	ThighC
Hadhana	49.5 [a]	96.5 [b]	73.0 [c]	183.0 [a]	209.0 [a.b]	95.5 [a.b]
Aouadi	46.0 [a]	107.0 [a.b]	83.0 [b.c]	178.0 [a]	176.0 [b]	100.0 [a.b]
Asail	46.0 [a]	98.8 [b]	82.0 [c]	184.8 [a]	199.6 [a.b]	84.8 [b]
Homor	49.3 [a]	114.6 [a]	96.7 [a.b]	198.6 [a]	228.0 [a]	103.6 [a]
Majaheem	51.5[a]	119.7 [a]	100.8 [a]	203.3 [a]	230.8 [a]	106.7 [a]
Saheli	45.0 [a]	103.0 [a.b]	115.0 [a]	179.0 [a]	220.0 [a]	91.0 [b]
Shaele	48.8 [a]	117.2 [b]	88.6 [b.c]	193.2 [a]	200.7 [a.b]	94.4 [b]
Shageh	54.0 [a]	133.0 [a]	119.0 [a]	193.0 [a]	235.0 [a]	104.0 [a]
Sofor	51.5 [a]	104.5 [a.b]	93.5 [a.b]	191.5 [a]	219.0 [a]	98.0 [a.b]
Waddah	51.4 [a]	122.8 [a]	97.9 [a]	190.2 [a]	226.0 [a]	104.1 [a]

Sexual differences

On average, the male measurements were higher in male for all the parameters. The male head was 11% longer, the neck 12% longer, the neck circumference 13% higher, the thigh circumference 14%. The difference in height (4%) and girth circumference (6%) was less marked.

The sexual difference was more important in Shageh breed: considering all the parameters, the body measurements of the Shageh male was 27% higher than female. This difference was 13% for Hadhana, 11% for Saheli, 10% for Waddah, 9% for Majaheem, 8% for Homor and Sofor, 6% for Aouadi, 5% for Shaele and 3% only for Asail.

Correlations between measurements

The correlation matrix was achieved for each group of camel (male or female) showing globally significant correlations between most of the quantitative parameters. There were no significant negative correlations. Among the parameters, in both sex, the thigh circumference appeared correlated to all the others parameters (Tables 3 and 4).

Table 3. Correlation matrix between the quantitative measurements of the female camel in Saudi Arabia. Significant coefficients at P <0.05 were in bold.

parameter	L head	L neck	Neck C	L teat	L udder	Height W	Girth C	Thigh C
L head	**1**	**0.540**	-0.034	0.132	**0.489**	**0.260**	**0.238**	**0.311**
L neck	**0.540**	**1**	0.104	**0.172**	**0.389**	**0.303**	**0.345**	**0.353**
Neck C	-0.034	0.104	**1**	**0.163**	-0.132	**0.348**	0.088	**0.233**
L teat	0.132	**0.172**	**0.163**	**1**	**0.294**	0.119	0.111	**0.201**
L udder	**0.489**	**0.389**	-0.132	**0.294**	**1**	0.116	**0.360**	**0.267**
Height W	**0.260**	**0.303**	**0.348**	0.119	0.116	**1**	**0.289**	**0.366**
Girth C	**0.238**	**0.345**	0.088	0.111	**0.360**	**0.289**	**1**	**0.410**
Thigh C	**0.311**	**0.353**	**0.233**	**0.201**	**0.267**	**0.366**	**0.410**	**1**

Table 4. Correlation matrix between the quantitative measurements of the male camel in Saudi Arabia. Significant coefficients at P <0.05 were in bold.

Variables	L head	L neck	Neck C	Height W	Girth C	Tigh C
L head	**1**	**0.537**	**0.310**	0.190	**0.286**	**0.439**
L neck	**0.537**	**1**	**0.388**	0.244	**0.331**	**0.434**
Neck C	**0.310**	**0.388**	**1**	0.249	**0.574**	**0.621**
Height W	0.190	0.244	0.249	**1**	**0.294**	**0.303**
Girth C	**0.286**	**0.331**	**0.574**	**0.294**	**1**	**0.568**
Tigh C	**0.439**	**0.434**	**0.621**	**0.303**	**0.568**	**1**

Classification of the females

The clustering of the female camel breeds was optimal with a partition within 4 groups of breeds which explained 59.6 % of the variance. A first group (type A) included Hadhana, Aouadi, Saheli, Shageh and Awrk breed. They were characterized by short dimensions and medium size udder (Figure 1 and Table 5). A second (type D) gathered Homor, Majaheem, Shaele, Sofor and Waddah. This group had significantly higher measurements (LH, LN, HW, GC, TC) and well developed udder. Zargah and Asail appeared different and separated from the 2 other groups. Zargah (type B) was medium but with high girth circumference. Asail (type C) was also medium but with low development of the udder and narrow chest.

Table 5. Mean body measurements of the 4 clusters of female camel breed in Saudi Arabia (in cm). [a,b;c] Means within column with different superscript differ (P < 0.05).

Cluster	Lhead	Lneck	cNeck	Lteat	Ludder	HeightW	GirthC	ThighC
A	42.1 [b]	93.3[b]	82.5 [a]	4.7 [b,c]	16.8 [b]	177.5 [b]	190.1 [b]	81.9 [b]
B	42.7 [a,b]	93.3 [b]	85.3 [a]	8.3 [a]	29.3 [a]	183.6 [a,b]	226.6 [a]	81.7 [b]
C	42.2 [b]	94.2 [b]	86.2 [a]	2.0 [c]	6.2 [c]	185.7 [a,b]	199.2 [a,b]	78.2 [b]
D	47.0 [a]	107.8 [a]	84.0 [a]	5.1 [a,b]	24.9 [a]	188.3 [a]	218.7 [a]	92.7 [a]

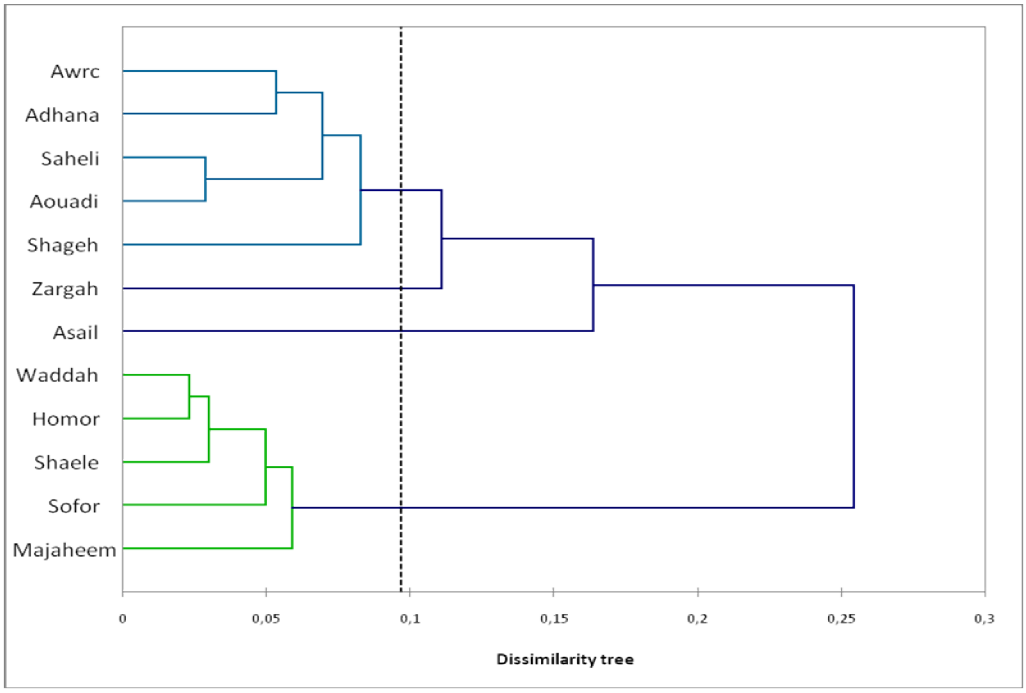

Figure 1. Classification tree of the 12 female camel breeds of Saudi Arabia according to their body measurements showing a partition within four types of camel breed.

Classification of the males

The optimal classification of male camel breeds gave a partition in 6 clusters explaining 77% of the variance (Figure 2). The type A (Asail and Shaele) had fine neck, thin leg and narrow chest, but was high. They are rangy camel useful for racing and riding. The type B (Homor, Majaheem, Sofor and Waddah) included big size camels. The type C included only Hadhana characterized by a short and fine neck and medium other measurements. The type D (Aouadi) was a small head animal with very narrow chest. The type E (Shageh) was the biggest type. The type F (Saheli) had a thick neck and a thin thigh with a medium chest (Table 6).

Table 6. Mean body measurements of the 6 clusters of male camel breed in Saudi Arabia (in cm). [a,b,c] Means within column with different superscript differ (P < 0.05).

Cluster	Lhead	Lneck	Cneck	Height	GirthC	ThighC
A	47.8[a]	110.6[a,b]	86.2[b]	190.2[a]	200.3[b]	91.0[b]
B	50.9[a]	119.1[a]	97.8[a]	194.7[a]	226.9[a]	104.0[a]
C	49.5[a]	96.5[b]	73.0[b]	183.0[a]	209.0[a,b]	95.5[a,b]
D	46.0[a]	107.0[a,b]	83.0[b]	178.0[a]	176.0[b]	100.0[a,b]
E	54.0[a]	133.0[a]	119.0[a]	193.0[a]	235.0[a]	104[a,b].0
F	45.0[a]	103.0[a,b]	115.0[a]	179.0[a]	220.0[a,b]	91.0[b]

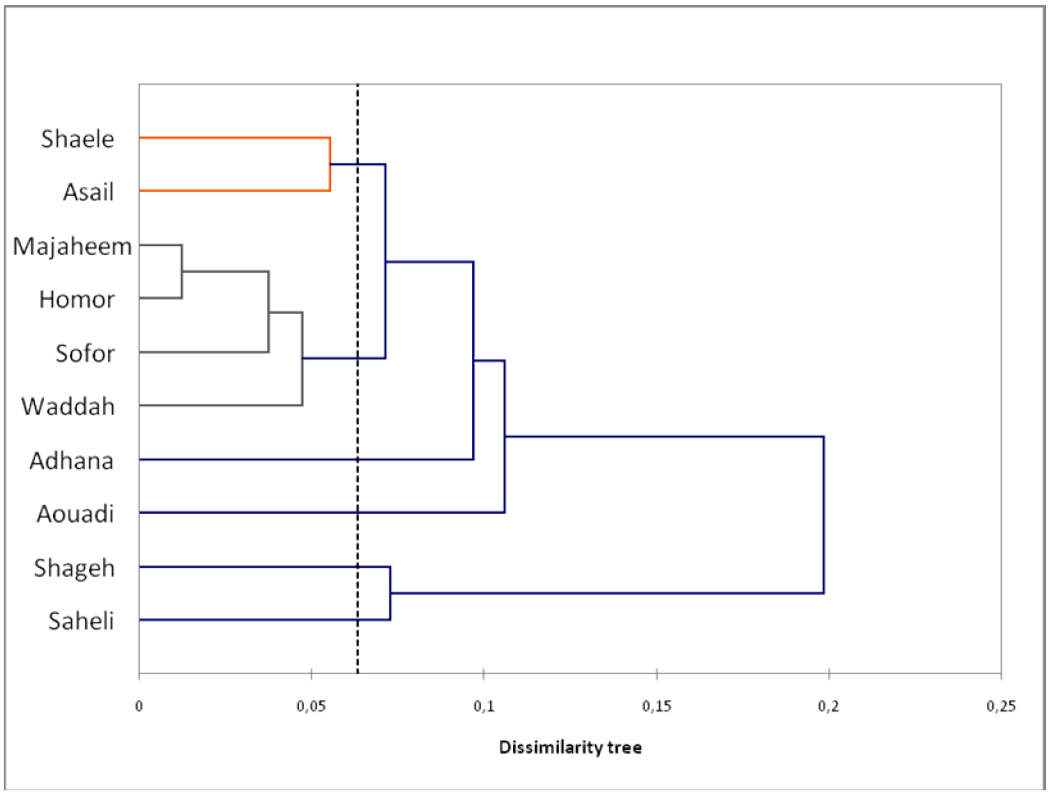

Figure 2. Classification tree of the 10 male camel breeds of Saudi Arabia according to their body measurements showing a partition within six types of camel breed.

Discussion

The body measurements were currently used for describing the camel phenotypes. Ishag et al. (2011) described the phenotypes of Sudanese camel breeds by measuring the heart girth, the barrel girth, the height at shoulder and the body weight. In our study, the barrel girth was not taken in account, because this measurement is depending of the hump size which varies according to the body condition score of the animal (Kamili et al., 2006). Indeed, the hump is the main fat storage form in camel representing on average 85% of the adipose tissue

(Faye et al., 2001a). Except for the thigh circumference, the body measurements were not significantly correlated to all the other measurements. The thigh conference seems to be a good indicator of the camel conformation, including the udder in female. Besides, the thigh circumference is commonly used by the butchers for predicting the weight of the carcass (Faye et al., 2001b).

The clustering of the different breeds was slightly different between male and female. The sexual difference in the general conformation of camel conducted naturally to a different distribution between the breeds. On average, the measurements were higher in male compared to female, but in different proportion according the breed.

By regarding, the only clustering of the females, a close relationship with the classification of Al-Eknah (unpublished results) based on the ecosystem (desert, hill, coast) or the use (riding, racing or production) was observed. Three main groups of camel could be described: (i) the big size camels from desert areas with good dairy potential (Homor, Majaheem, Waddah, Shaele, Sofor); (ii) the small size camels from hill or beach having multipurpose vocation (Aouadi, Awrk, Saheli, Hadhana); (iii) the medium size rangy camel breed for riding and racing (Asail, Zargeh, Shageh).

This classification is corresponding partially to the typology of Blanc and Hennesser (1989) which distinguish (i) the big size camel living in desert plain, (ii) the medium size camel used for riding, and (iii) the small size camel living in mountainous areas.

In Saudi Arabia, these phenotypes are linked partly to different farming system (Abbas et al., 2000; Al-Khamis and Young, 2006): (i) the big size camels are mainly used for dairy production, adapted to desert areas but able to undergo intensification process with settlement around the towns, (ii) the small size camels from coastal or hill environment are mainly associated to small scale camel farm in more favorable climatic environment characterized by a diversification of the livestock rearing activities and the use of camel as multipurpose animals, (iii) the medium size camels are linked to racing stables where the animals received enriched diet and undergo special exercise for competitions. For racing camels however, genetic exchanges with neighboring countries could lead to specific classification (Shorepy, 2011).

The described phenotypes are also mainly linked to geographical distribution as it has been observed in other countries (Ould Ahmed et al., 2010).

The big size camels are more common in the northern and eastern part of the Kingdom of Saudi Arabia, and the small size camel in the south-western part. The medium size camel having a riding and racing vocation, they are more widely distributed in the country. The preliminary results of camel genotyping in Saudi Arabia produce similar conclusions showing a geographical classification distinguishing the camel in the northern part from the camel breeds in the East, themselves different from the camel breed living in the western mountainous part of the Kingdom (Mahrous et al., 2011). These results were recently confirmed (Almathen et al., 2012) revealing three genetically separated groups of dromedary in Saudi Arabia with distinct, although likely overlapping, geographic distribution in the Southern west region (Awrk, Awadi, Hadhana and Saheli), East region (Majaheem and Shaele) and Northern part (Waddah, Sofor, and Homor) of the Kingdom of Saudi Arabia respectively. The results also highlighted that the Awrk and Awadi camel populations were genetically distinct from the other camel populations.

Conclusion

The fine phenotype description could be a first step for establishing a classification of the different breeds or types, and for valorizing the camel biodiversity in the Kingdom of Saudi Arabia. Elsewhere, the current changes in the camel farming systems (settlement, intensification, in-door feeding systems, implementation around the towns, etc.,) would increase the demand for more productive and specialized animals. For this reason, a clear description of the potential is an important step for the future improvement of the camel breeds. The present phenotype study limited to the body measurements would be an opportunity to underline the richness of this emblematic animal for all the Saudi people whatever their social rank or the place where they are living.

Acknowledgements

This study has been achieved within FAO project UTF/SAU/021/SAU with the support of Camel and range research Center (CRRC). The authors thank Mr Sallal Issa Al-Mutairi, head of the CRRC for his encouragements and support. We thank also all the camel owners and shepherds who help us to manage their animals and gave us their agreement for measuring them. This work was done with the powerful help of all staff of Ministry of Agriculture in different regions of the Kingdom. Thanks also to FAO regional officer, Dr Mohammed Bengoumi who supported this project

from the beginning. And finally, thanks to all the camel who accepted to be measured.

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