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Relationship between udder morphology traits, alveolar and cisternal milk compartments and machine milking performances of dairy camels (*Camelus dromedarius*)

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Abstract

A total of 22 dairy dromedary camels under intensive conditions in late lactation (275 ± 24 days) were used to study the relationship between external and internal udder morphology and machine milking performances. Measurements of udder and teat morphology were obtained immediately before milking and in duplicate. Individual milk yield, lag time and total milking time were recorded during milking, and milk samples were collected and analyzed for milk composition thereafter. Cisternal and alveolar milk volumes and composition were evaluated at 9 h milking interval. Results revealed that dairy camels had well developed udders and milk veins, with medium sized teats. On average, milk yield as well as milk fat and protein contents were 4.80 ± 0.50 L d^{-1}, 2.61 ± 0.16% and 3.08 ± 0.05%, respectively. The low fat values observed indicated incomplete milk letdown during machine milking. Lag time, and total milking time were 3.0 ± 0.3, and 120.0 ± 8.9s, on average, respectively. Positive correlations ($p < 0.05$) were observed between milk yield and udder depth ($r = 0.37$), distance between teats ($r = 0.57$) and milk vein diameter ($r = 0.28$), while a negative correlation was found with udder height ($r = –0.25$, $p < 0.05$). Cisternal milk accounted for 11% of the total udder milk. Positive correlations were observed between total milk yield and volume of alveolar milk ($r = 0.98$; $p < 0.001$) as well as with volume of cisternal milk ($r = 0.63$, $p < 0.05$). Despite the low udder milk storage capacity observed in dairy camels, our study concluded that the evaluated dromedary sample had adequate udder morphology for machine milking. Finally, positive relationships were detected between milk yield and udder morphology traits of dairy camels.

Additional key words: dromedary camel; milk production; udder traits; cisternal milk; intensive system.

Introduction

Dromedary camels (*Camelus dromedarius*) population in Saudi Arabia is estimated at 830,000 heads (Agriculture Statistical Year Book, 2010) distributed in different parts of the country. Camels are one of the largest terrestrial mammals that inhabit areas where diurnal ambient temperatures exceed that of their body temperatures (Al-Haidary, 2006). Despite the severe conditions confronted in their natural environmental habitat, dairy camels are capable —in comparison to other farm animals— of taking the advantages of the

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Abbreviations used: BW (body weight); CMT (California mastitis test); EC (electrical conductivity); LSD (least significant difference); SCC (somatic cell count).

limited resources to produce a daily milk yield ranging between 4 to 18 L per head (Saoud *et al.,* 1988; Gaili *et al.,* 2000; Aljumaah *et al.,* 2011).

Milking management can be regarded as a key step in the milk production chain. Despite the considerable number of studies that have been conducted on milking management of dairy cattle, sheep and goats, little information is available on lactation biology of dairy camels. Hand milking is the predominant milking system in camels. Nevertheless, as a result of the market demand, machine milking have recently been adopted in intensive camel dairy farms for commercial milk production (Wernery *et al.,* 2004; Faye, 2005; Hammadi *et al.,* 2010).

Exploring the external as well as the internal morphology traits of the udder was proven useful for improving milk yield and milking ability in dairy animals (Labussiere, 1988). Zayeed *et al.* (1991) reported high variations (attributed to several factors such as breed, lactation stage, parity number and disease) in the size and length of udders and teats in dairy camels. Similarly, Abdallah & Faye (2012) observed a clear variability in teats and udder length in 12 breeds of camels in Saudi Arabia, while some of the udder morphometric measurements of Lahween dromedary camel in Sudan have proved to possess an impact on their milk yield (Eisa *et al.,* 2010). Additionally, dairy camels are characterized by the development of the udder and milk veins (Wardeh & Al-Mustafa, 1990).

The secreted milk is stored in two anatomical compartments as alveolar and cisternal milk. Animals that store large amounts of milk in the gland cistern generally produce more milk, and tolerate extended milking intervals (Knight & Dewhurst, 1994; Ayadi *et al.,* 2003). Therefore, studying the pattern of milk accumulation and storage in the udder can help improving the techniques and routines for machine milking in camels.

As far as we know, there is a paucity of data studying the relationship between udder morphology traits and milk yield of dairy dromedary camels. Therefore, the aim of this study was to evaluate the external (morphological) and internal (milk compartments) udder traits and machine milking performances in lactating dromedaries managed under intensive conditions in Saudi Arabia.

Material and methods

Animals and management

Twenty two multiparous lactating dromedary camels (590 ± 40 kg BW) in late lactation (275 ± 24 days) with apparent healthy udders and maintained at the farm of Camel and Range Research Center (Skaka, Al-Jouf, Saudi Arabia) were used in the present study. All camels were identified by electronic ceramic boluses (Rumitag, Esplugues de Llobregat, Barcelona, Spain) according to Salama *et al.* (2012). The boluses contained a 32×3.8 mm radiofrequency transponder (Ri-Trp-RR2B-06, Tiris, Almelo, the Netherlands) working at a low frequency (134.2 kHz).

Lactating camels suckled their calves freely during the 1st month of lactation. Then, the dams were introduced to twice daily (08:00 and 17:00 h) machine milking being the calves from their dams and allowed to suckle for striping after milking. Calves were weaned at 12th month of age.

The milking routine included: milk let-down by calves; udder preparation, machine milking, and final stripping by the calf. Camels were milked using a portable machine milking (Kurstsan Milking Machine, type SSM, Istambul, Turkey). The milking clusters had a claw and four individual teats cups with rubber liners and stainless steel cups. The weight of the milking cluster and the diameter of the lines were 2.6 kg and 23 mm, respectively. The milking machine was set at 45 kPa, 60 pulses min^{-1}, and 60:40 pulsation ratio, and equipped with recording jars and a low milk pipeline.

Daily ration per animal consisted of alfalfa hay *ad-libitum* supplemented with 3 kg d^{-1} of barley grain and 1 kg d^{-1} of wheat bran. Camel had free access to clean tap water.

Udder morphology measurements

Measurements of udders and teats were taken in duplicate in the evening (17:00) just before the p.m. milking. Measurements (cm) were the following (Fig. 1); udder depth (UD, distance between the rear udder attachment and the base of teat), udder height (UH, distance from the ground to the base of the teats), udder length (UL, distance between the front and rear attachments of the udder), teat length (TL, distance from the teat insertion base to the teat orifice), teat diameter (TD, measured in the middle of the teat using a Vernier caliper; ASAHIT, Hamburg, Germany), teat separation (TS, distance between front and rear teat ends), teat-end to floor (TEF, vertical distance between the teat-end and the floor), and milk veins diameter (MVD) measured approximately at 20 cm from the udder with the same Vernier caliper.

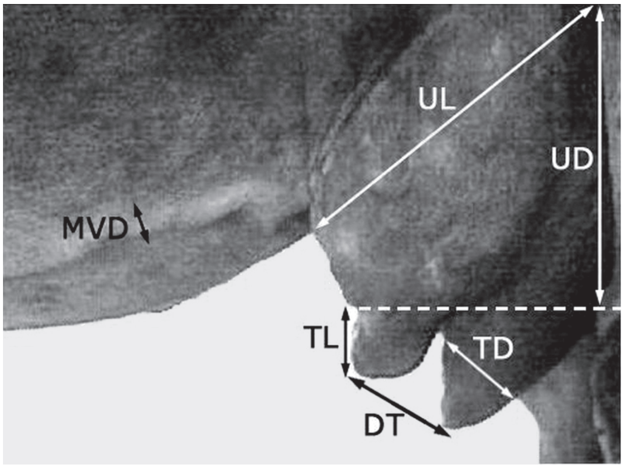

Figure 1. Measurements of udders and teats morphology in dairy dromedary camels. UD: udder depth. UL: udder length. TL: teat length. TD: teat diameter. DT: distance between teats. MVD: milk veins diameter.

Milk yield and milking characteristics

Individual milk yield, lag time (time from cup attachment to the first drops of milk being observed) and milking time (time to obtain all machine milk fractions) were recorded during milking. Milk samples were collected and analyzed for fat, protein, lactose and total solids using an automatic milk analyzer device (Lactoscan MCC, Milkotronic Ltd, Stara Zagora, Bulgaria) previously calibrated for camel milk.

Assessment of udder health was performed by California mastitis test (CMT), somatic cell count (SCC) and electrical conductivity (EC). The CMT was performed using Bovivet CMT test kit (CMT Bovi-Vet, Kruuse, Langeskov, Denmark), the SCC (cells mL^{-1}) was determined using NucleoCounter SCC-100 (ChemoMetec, Allerød, Denmark), while the EC (mS cm^{-1}) was determined using a conductivity meter (direct-ION, Dover, Kent, UK).

Cisternal and alveolar udder compartments

To study the milk partitioning between cisternal and alveolar udder compartments, a subset of 10 late lactating camels (255 ± 45 days) were used 9 h after milking. Dams were separated from their calves and moved to a restraining pen (unfamiliar surroundings) to reach a stressful situation for preventing spontaneous milk letdown during udder manipulation according to Bruckmaier *et al.* (1993). At first, cisternal milk volume was evacuated by machine milking. Thereafter, dams received intramuscular injection of oxytocin (20 IU/camel; Biocytocine, Laboratoires Biové, Arques, France) to induce milk letdown. Alveolar milk was obtained by machine milking and then volume was recorded. Milk samples of each fraction were collected and analyzed for; fat, protein, lactose, and solids-not-fat using the Lactoscan.

Statistical analysis

Data were analyzed for least squares means using the proc GLM of Statistical Analysis System (SAS version 9.2, SAS Inst. Inc., Cary, NC, USA). Significant differences between means were determined by Fischer's least significant difference (LSD). The overall level for statistical significance was set at $p < 0.05$. The degree of association between measurements was analyzed using the Proc CORR of SAS, where the correlation coefficients (r) of Pearson were computed.

Results

No subclinical mastitis was detected in any of the udders during the experimental period as indicated by the CMT (< 1), SCC, and EC. On average, milk yield as well as milk fat and protein contents were 4.80 ± 0.50 L d^{-1}, 2.61 ± 0.16% and 3.08 ± 0.05%, respectively (Table 1). Low fat:protein ratio (< 1.0) was observed. Average values of lag time and milking time were 3.0 ± 0.3 s and 120.0±8.9 s, respectively (Table 1), for the milk yield obtained at the evening milking (1.99 ± 0.39 L). No differences were detected between right and left teats measurements (Table 2); therefore, values were averaged and jointly discussed. Results revealed that dairy camels had a developed udder and milk vein, with medium size teats (Table 2).

Positive correlations were observed between udder height and both teat-end floor distances ($r = 0.75$ to 0.87, $p < 0.05$) as well as between teat length and diameter (r = 0.38 to 0.75, $p < 0.05$), while negative correlation was obtained between teats diameter and distance between teats ($r = -0.23$, $p = 0.09$) (Table 3). Furthermore, milk yield was correlated positively ($p < 0.05$) with udder depth ($r = 0.37$), distance between teats ($r = 0.57$) and milk vein diameter ($r = 0.28$), while a negative correlation was found with udder height ($r = -0.25$) (Table 3). Positive correlations were observed between

Table 1. Least square means (LSM) of milk production, milk composition and udder health of dromedary camels at late lactation

Item	LSM ± SE	Range
Milk production		
[1]Milk yield, L d^{-1}	4.80 ± 0.50	1.50-9.70
[2]$FCM_{3\%}$, L d^{-1}	4.35 ± 0.35	1.55-7.35
Lag time, s	3.0 ± 0.3	0.5-6.0
Milking time, s	120.0 ± 8.9	44-227
Milk composition (%)		
Fat	2.61 ± 0.16	1.26-3.87
Protein	3.08 ± 0.05	2.58-3.51
Fat: protein ratio	0.84 ± 0.05	0.43-1.36
Lactose	4.22 ± 0.07	3.53-4.77
Total solids	12.90 ± 0.21	10.78-14.63
Solids not fat	10.28 ± 0.16	8.56-11.70
Udder health		
SCC (× 1,000), cells mL^{-1}	189.8 ± 100.8	10-2,000
Log (SCC)	5.16 ± 0.46	4.0-8.6
[3]EC, mS cm^{-1}	5.34 ± 0.22	3.56-6.85

[1] Total of 08:00 and 17:00 h milking. [2] Fat corrected milk at 3% fat according to Aljumaah *et al.* (2012b): [$FCM_{3\%}$ = Milk yield × (0.197 × Fat (%) + 0.408)]. [3] Electrical conductivity.

Table 2. Least square means (LSM) of udder morphology traits (cm) in dromedary camels measured at late lactation

Item	LSM ± SE	Range
Udder		
Depth	44.50 ± 0.64	39.00-49.00
Length	49.68 ± 0.90	43.00-56.00
Height	107.48 ± 1.44	93.00-122.50
Front teats[1]		
Length	4.86 ± 0.31	3.00 -8.80
Diameter	2.94 ± 0.20	1.60-5.40
Teat-end-floor	102.42 ± 1.72	89-109
Rear teats[2]		
Length	5.32 ± 0.30	3.40-8.40
Diameter	2.99 ± 0.21	2.00-5.60
Teat-end-floor	101.75 ± 1.47	91-110
Teat distance[3]	9.69 ± 0.64	3.70-17.00
Milk vein diameter	2.31 ± 0.09	1.80-3.50

[1,2] Averaged values for left and right teats are presented. [3] Distance between front and rear teats.

milking time and milk yield ($r = 0.61$; $p < 0.01$) as well as distance between teats ($r = 0.42$, $p = 0.06$). However, lag time was not correlated with milk yield and all udder measurements.

No difference was detected between right and left cisternal milk; therefore, values were averaged and jointly discussed. Cisternal milk accounted for only 11% of the total udder milk (Table 4). Volume of cisternal milk did not correlate ($r = 0.46$; $p = 0.21$) with alveolar milk. However, positive correlations were observed between milk yield and volume of alveolar ($r = 0.98$; $p < 0.001$) as well as volume of cisternal milk ($r = 0.63$, $p < 0.05$). Fat content in alveolar milk was greater (21%; $p < 0.05$) than in cisternal milk (Table 4). However, protein, lactose and solids-not-fat contents did not differ between cisternal and alveolar milk fractions (Table 4). The SCC

Table 3. Correlation coefficients between udder traits and milk yield in machine milking dromedary camels

Traits[1]	FTL	RTL	FTD	RTD	FTEF	RTEF	DT	UD	UL	UH	MVD	MY	DMY
FTL													
RTL	0.55**												
FTD	0.69**	0.52**											
RTD	0.38*	0.75**	0.59**										
FTEF	–0.08	–0.53	–0.14	–0.75**									
RTEF	–0.15	–0.54	–0.18	–0.82**	0.96**								
DT	0.02	–0.15	–0.22*	–0.23*	–0.14	–0.13							
UD	0.30	0.08	0.54**	0.35	0.30	0.24	0.06						
UL	–0.22	–0.34	–0.38	–0.51**	–0.42	–0.29	0.30	–0.31					
UH	0.17	0.03	0.34	0.19	0.75**	0.87**	–0.12	0.12	–0.28				
MVD	–0.03	–0.15	0.15	–0.06	0.15	0.09	0.37	0.36	0.07	–0.17			
MY	–0.04	–0.21	–0.12	–0.31	0.35	0.21	0.57**	0.37**	0.33	–0.26**	0.28**		
DMY	–0.06	–0.15	–0.13	–0.20	0.11	0.06	0.61**	0.29**	0.22	–0.19	0.34*	0.87**	

[1] DT: distance between front and rear teats, DMY: total daily milking by twice-daily milking (08:00 and 17:00), MVD: milk vein diameter, MY: milk yield produced during 9 h after milking, UD: udder depth, UH: udder high, UL: udder length, FTD: front teat diameter, RTD: rear teat diameter, FTEF: front teat-end floor distance, RTEF: rear teat-end floor distance, FTL: front teat length, and RTL = rear teat length. * $p < 0.10$; ** $p < 0.05$.

Table 4. Cisternal and alveolar milk volumes and their composition at 9 h milking interval in lactating dromedary camel

Item	Udder compartment		p values
	Cisternal	Alveolar	
Milk yield, L	0.33 ± 0.08^b	2.65 ± 0.31^a	0.001
Milk composition, %			
Fat	2.98 ± 0.17^b	3.59 ± 0.18^a	0.028
Protein	2.90 ± 0.05	2.99 ± 0.06	0.988
Lactose	4.27 ± 0.08	4.26 ± 0.08	0.913
Solids-not-fat	8.02 ± 0.14	8.01 ± 0.15	0.970
Udder health			
SCC (× 1,000), cells mL^{-1}	429 ± 213	281 ± 198	0.618
Log (SCC)	6.00 ± 0.54	4.44 ± 0.47	0.443

[a,b] Values with different superscript letters in the same row indicate significant differences at $p < 0.05$.

averaged 355 ± 104 (×1,000 cells mL^{-1}), and did not change significantly between cisternal and alveolar milk fractions, although it was numerically greater in cisternal milk compared to alveolar milk (Table 4).

Discussion

Exploring the udder morphology as well as studying milk accumulation and storage in the udder are necessary aspects for improving milk yield and machine milking ability of dromedary camels.

In the current study, introducing machine milking did not negatively affect the udder health of dromedary camels as indicated by CMT, SCC, and EC. This agrees with previous conclusions of Wernery *et al.* (2004) and Hammadi *et al.* (2010) on dromedary milked under intensive conditions.

Daily milk yield as well as protein, lactose, and total solids contents were within the normal ranges reported in literature of dromedary camels under intensive conditions (Konuspayeva *et al.,* 2009; Aljumaah *et al.,* 2012a; Nagy *et al.,* 2013). Meanwhile, milk fat content was lower than those reported by Ayadi *et al.* (2009) and Hammadi *et al.* (2010). The low fat values observed in our case resulted in an inverted fat:protein ratio (Table 1), which was a consequence of the incomplete milk letdown during the machine milking (*e.g.* milk without stimulatory calf suckling or inefficient prestimulation machine milking). Nevertheless, the incidence of low milk fat syndrome as a consequence of low proportion of forage in the diet should not be discarded and would need further research.

Regarding milking characteristics, mean value of lag time (3 s; Table 1) was shorter than observed by Hammadi *et al.* (2010; 36 s) on machine milked dromedary camels, which may be attributed to a direct consequence of using calves for inducing milk letdown in our case. Moreover, the lag time in dairy cows depends on the degree of udder filling which varied with interval between milkings, stage of lactation and udder cistern volume (Bruckmaier, 2005). On the other hand, mean values of total milking time (120 s) determined herein were similar to the results previously reported by Wernery *et al.* (2004) but shorter than the previously observed by Hammadi *et al*. (2010).

According to our observations, dromedary camels had a developed udder and milk vein with medium sized teats. Udder height measured in the current study was similar to values reported by Eisa *et al.* (2010) on dromedary camels. However, udder length and depth values were greater than the results previously reported by Eisa *et al.* (2010) and Abdallah & Faye (2012) on dromedary camels, but within the same range reported for cows (Rogers & Spenser, 1991; Alfonso *et al.,* 2011) and buffaloes (Prasad *et al.,* 2010). Furthermore, teat lengths were similar to values reported in different breeds of camel in Saudi Arabia (Abdallah & Faye, 2012), but were greater than values observed in Sudanese Lahween camel (Eisa *et al.,* 2010). Teat diameter values were similar to those reported by Eisa *et al.* (2010). Meanwhile, the distance between teats was greater than the results previously reported by Eisa *et al.* (2010) on camel, but within the same range reported by Alfonso *et al.* (2011) on cows and Prasad *et al.* (2010) on buffaloes. Similar results were observed for milk vein diameter trait by Eisa *et al.* (2010) in camels and Rizzo *et al.* (2012) in cows.

With regard to the correlation coefficients between udder traits, significant positive correlations were observed between teat length and diameter, which could indicate that longer teats were wider at the mid-point. The high positive correlations among these measurements suggest that only one single teat measurement could be included in the selection schemes. Furthermore, the positive correlations observed between daily milk yield and udder depth, distance between teats as well as milk vein diameter traits agree with Eisa *et al.* (2010). The well developed milk veins observed in our work may reflect a high yield milk secretion potential in Saudi dromedary camel. Similarly to our results, negative correlations were obtained between daily milk yield and udder height trait in dromedary camels (Eisa *et al.,* 2010) and cows (Rogers & Spenser, 1991). However, no significant correlations were observed between daily milk yield and teat length and diameter as reported by Eisa *et al.* (2010). Accordingly, dromedary camels showed adequate udder morphology traits to the machine milking, and subsequently can be adopted in breeding programs of dromedary camels in Saudi Arabia.

The cisternal milk fraction varied according to species, breed, lactation stage, parity and milking intervals (Caja *et al.,* 2004; Salama *et al.,* 2004; Castillo *et al.,* 2008). According to Yagil *et al.* (1999), camels do not have a noticeable mammary cistern which is contradicted by our results. Although the percentage of cisternal milk obtained in our study at 9-h milking interval was lower than that reported by Ayadi *et al.* (2009) in camels at 24-h milking interval (20 %), Ayadi *et al.* (2003) in cows at 12-h milking interval (30%), and McKusick *et al.* (2002) in ewes at 8-h milking interval (38%), our result was greater than reported by Thomas *et al.* (2004) in buffaloes at 12-h milking interval (5%). Animals that store large amounts of milk in the gland cistern generally produce more milk, milked faster and tolerate extended milking intervals (Knight & Dewhurst, 1994; Ayadi *et al.,* 2003). The relatively small cistern size of camels may impair milk secretion and subsequently the total milk yield especially for late lactation and extended milking intervals (Ayadi *et al.,* 2009). Consequently, efficient udder stimulation is recommended in dromedary camels to maximize machine fraction and to minimize stripping fraction during machine milking. Cisternal milk was correlated positively with total milk yield, which might indicate that cisternal size could be used for predicting milk yield in dromedary camels.

In the current study, the parameters of machine milking were set for cows as milking parameters for camel milking are unknown. It is necessary to perform further research work to determine the suitable parameters for machine milking in dairy camels.

Fat content in alveolar milk was greater than in cisternal milk for the 9-h milking interval. This difference can be explained by the viscosity and large size of fat globules which are accumulated in the alveolar compartment. This result agrees with those previously reported in camels (Ayadi *et al.,* 2009), sheep (McKusick *et al.,* 2002) and cows (Davis *et al.,* 1998; Ayadi *et al.,* 2004). On the other hand, no significant difference was observed between milk protein percentage of cisternal and alveolar milk. Protein in milk is primarily found in form of small casein micelles (Cowie & Tindal, 1971) within the aqueous fraction of the milk. Therefore, proteins pass freely from the alveolar to the cistern compartment without being dependent on milk ejection reflex as fat matter. This result agrees with those previously reported in dairy cows (Ayadi *et al.,* 2004), but disagree with results of Ayadi *et al.* (2009) on camels where alveolar milk protein content was found to be greater than in cisternal milk. The discrepancy between the current and previous results in camels could be explained by the difference in the interval between milking, which was 24-h in the study of Ayadi *et al.* (2009). Furthermore, SCC did not change between cisternal and alveolar milk fractions. Similar results were obtained in milk fraction of dairy cows (Ontsouka *et al.,* 2003), dairy ewes (McKusick *et al.,* 2002; Castillo *et al.,* 2008) and dairy goats (Salama *et al.,* 2005).

In conclusion, the present study shows that lactating dromedary camels had a developed udder and milk vein with medium size teats, indicating adequate udder morphology for machine-milking. Some udder morphology traits had a positive correlation with milk yield and can be adopted for genetic improving in the breeding programs of dromedary camels in Saudi Arabia. Udder cistern sizes observed in our study were relatively small. This recommends implementing a milking routine with an efficient pre-stimulation before milking to avoid the negative effects of an incomplete milk letdown during machine-milking and to ultimately improve the milk production, milking ability and udder health of dairy camels. Further research is required to confirm these results at early and mid stage of lactation.

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References

Abdallah HR, Faye B, 2012. Phenotypic classification of Saudi Arabian camel (*Camelus dromedarius*) by their body measurements. Emir J Food Agric 24: 272-280.

Agriculture Statistical Year Book, 2010. Agricultural Research and Development Affairs, Department of Studies, Planning and Statistics. Ministry of Agriculture, Saudi Arabia. 22: 163-165.

Alfonso RE, Herrera HJ., Lemus FC, Ortega CME, Cortez RC, Pérez PJ, 2011. Morphometric characterization of American Brown Swiss cows in tropical region of Chiapas, Mexico. J Anim Vet Adv 4: 454-459.

Al-Haidary AA, 2006. Seasonal variation in thermoregulatory and some physiological responses of Arabian camel (*Camelus dromedarius*). J Saudi Soc Agr Sci 5: 30-41.

Aljumaah RS, Almutairi FF, Ayadi M, Alshaikh MA, Aljumaah AM, Hussein MF, 2011. Factors influencing the incidence of subclinical mastitis in lactating dromedary camels in Riyadh region, Saudi Arabia. Trop Anim Health Prod 43: 1605-1610.

Aljumaah RS, Almutairi FF, Ismail E, Alshaikh MA, Sami A, Ayadi M, 2012a. Effects of production system, breed, parity and stage of lactation on milk composition of dromedary camels in Saudi Arabia. J Anim Vet Adv 11: 141-147.

Aljumaah RS, Ayadi M, Alshaikh MA, Casals R, Caja G, 2012b. Milk components relationship and energy corrected milk standardization for dairy camels. Proc 3th Int Conf of Camelid Research and Development, Muscat (Sultanate of Oman), 29 Jan-01 Feb. pp: 423-424.

Ayadi M, Caja G, Such X, Knight CH, 2003. Effect of omitting one milking weekly on lactational performances and morphological udder changes in dairy cows. J Dairy Sci 86: 2352-2358.

Ayadi M, Caja G, Such X, Rovai M, Albanell E, 2004. Effect of different milking intervals on the composition of cisternal and alveolar milk in dairy cows. J Dairy Res 71: 304-310.

Ayadi M, Hammadi M, Khorchani T, Barmat A, Attigui M, Caja G, 2009. Effects of milking interval and cisternal udder evaluation in Tunisian Maghrebi dairy dromedaries (*Camelus dromedarius* L.). J Dairy Sci 92: 1452-1459.

Bruckmaier RM, 2005. Normal and disturbed milk ejection in dairy cows. Dom Animal Endocrin 29: 268-273.

Bruckmaier RM, Schams D, Blum JW, 1993. Milk removal in familiar and unfamiliar surroundings: Concentrations of oxytocin, prolactin, cortisol and β-endorphin. J Dairy Res 60: 449-456.

Caja G, Ayadi M, Knight CH, 2004. Changes in cisternal compartment based on stage of lactation and time since milk ejection in the udder of dairy cows. J Dairy Sci 87: 2409-2415.

Castillo V, Such X, Caja G, Casals R, Albanell E, Salama AAK, 2008. Effect of milking interval on milk secretion and mammary tight junction permeability in dairy ewes. J Dairy Sci 91: 2610-2619.

Cowie AT, Tindal JS, 1971. The physiology of lactation. Camelot Press Ltd, London.

Davis SR, Farr VC, Copeman PJA, Carruthers VR, Knight CH, Stelwagen K, 1998. Partitioning of milk accumulation between cisternal and alveolar compartments of the bovine udder: relationship to production loss during once daily milking. J Dairy Res 65:1-8.

Eisa MO, Ishag IA, Abu-Nikhaila AM, 2010. A note on the relationships between udder morphometric and milk yield of Lahween camel (*Camelus dromedarius*). Livest Res Rural Develop. Available in http://www.lrrd.org/lrrd22/10/eisa22188.htm [30 December 2012].

Faye B, 2005. Productivity potential of camels. Proc Int Workshop of Life and Behavioural Sciences. Amsterdam (Netherlands), 17 Sep. pp: 127-134.

Gaili ESE, Al-Eknah MM, Sadek MH, 2000. Comparative milking performance of three types of Saudi camels (*Camelus dromedarius*). J Camel Pract Res 7: 73-76.

Hammadi M, Atigui M, Ayadi M, Barmat A, Belgacem A, Khaldi G, Khorchani T, 2010. Training period and short time effects of machine milking on milk yield and milk composition in Tunisian Maghrebi camels (*Camelus dromedarius* L.). J Camel Pract Res 17: 1-7.

Knight CH, Dewhurst RJ, 1994. Once daily milking of dairy cows: Relationship between yield loss and cisternal milk storage. J Dairy Res 61: 441-449.

Konuspayeva G, Faye B, Loiseau G, 2009. The composition of camel milk: a meta-analysis of the literature data. J Food Compos Anal 22: 95-101.

Labussière J, 1988. Review of physiological and anatomical factors influencing the milking ability of ewes and the organization of milking. Livest Prod Sci 18: 253-273.

McKusick BC, Thomas DL, Berger YM, Marnet PG, 2002. Effect of milking interval on alveolar versus cisternal milk accumulation and milk production and composition in dairy ewes. J Dairy Sci 85: 2197-2206.

Nagy N, Thomas S, Marko O, Juhasz J, 2013. Milk production, raw milk quality and fertility of dromedary camels (*Camelus dromedarius*) under intensive management. Acta Vet Hung 61:71-84.

Ontsouka CE, Bruckmaier RM, Blum JW, 2003. Fractionized milk composition during removal of colostrums and mature milk. J Dairy Sci 86: 2005-2011.

Prasad RMV, Sudhakar K, Raghava Rao E, Ramesh Gupta B, Mahender M, 2010. Studies on the udder and teat morphology and their relationship with milk yield in Murrah buffaloes. Livest Res Rural Develop 22: 20. Available in http://www.lrrd.org/lrrd22/1/pras22020.htm. [30 December 2012].

Rizzo A, Mutinati M, Minoia G, Pantaleo M, Sciorsci RL, 2012. The impact of oxytocin on the hemodynamic features of the milk vein in dairy cows: a color Doppler investigation. Res Vet Sci 93: 983-988.

Rogers GW, Spenser SB, 1991. Relationships among udder and teat morphology and milking characteristics. J Dairy Sci 74: 4189-4194.

Salama AAK, Caja G, Such X, Peris S, Sorensen A, Knight CH, 2004. Changes in cisternal udder compartment induced by milking interval in dairy goats milked once- or twice-daily. J Dairy Sci 87: 1181-1187.

Salama AAK, Caja G, Such X, Casals R, Albanell E, 2005. Effect of pregnancy and extended lactation on milk production and udder compartments in dairy goats milked once daily. J Dairy Sci 88: 3894-3904.

Salama OH, Caja G, El-Sayed H, El-Shafei MH, Salama AAK, Ayadi M, 2012. Proc 3th Int Conf of Camelid Research and Development, Muscat (Sultanate of Oman), 29 Jan-1 Feb. pp: 165-166.

Saoud A, Al-Motairy O, Hashimi SE, 1988. Camels in Saudi Arabia. Camel Newsletter 4: 13-16.

Thomas SCH, Svennersten-Sjaunja K, Bhosrekar MR, Bruckmaier RM, 2004. Mammary cisternal size, cisternal milk and milk ejection in Murrah buffaloes. J Dairy Res 71: 162-168.

Wardeh MF, Al-Mustafa M, 1990. Camel breed types in the Arab countries North and West Africa. Proc Arab Symp of camel husbandry and diseases and methods of their control. Alger (Algeria), 24-26 March. pp: 105.

Wernery U, Juhasz J, Nagy P, 2004. Milk yield performance of dromedaries with an automatic bucket milking machine. J Camel Pract Res 11: 51-57.

Yagil R, Creveld CV, Abu-R'kaib G, Merin U, 1999. Milk let-down in camels. J Camel Pract Res 6: 27-29.

Zayeed AA, Magdub AB, Shareha AM, El-Sheikh A, Manzally M, 1991. Conf of camels in the Arab World. University of Omar El-Mukhtar, 1st ed [Arabic].Tripoli (Libya). pp: 115.