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TRAINING PERIOD AND SHORT TIME EFFECTS OF MACHINE MILKING ON MILK YIELD AND MILK COMPOSITION IN TUNISIAN MAGHREBI CAMELS (*Camelus dromedarius*)

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ABSTRACT

Six healthy Maghrebi dairy camels at mid lactation were used in 2 trials to assess the camel training period for machine milking, and the short time effects of machine milking vs. hand milking on some milk production parameters and physicochemical characteristics in milk. Before the study, dams were reared in oasis intensive system and hand-milked twice. In trial 1 which lasted for 2 weeks, camels were trained for machine milking. In trial 2, camels were monitored during 2 successive weeks; on the first week they were hand-milked and on the second week, they were machine milked.

Trial 1. Over days of training, the animals became less hostile and the total time between entering and exiting did not exceed 15 min. The lag time, after oxytocin injection, did not change and averaged 29.6 ± 3.0 s. Nevertheless, milking time increased with the change of the milk production and averaged 7.5 ± 0.4 min and 9.4 ± 0.6 min, during the first and the second week, respectively.

On the 2nd day of machine milking, daily milk yield decreased slightly (-6%) compared to the day (-2) before the start of machine milking. This production increased to 7.48 ± 0.52 l on day 13 of training. On the second week of the training period, no difference was observed between the daily milk yields. During training camels for machine milking, total milk solids, protein and ash contents did not vary. Milk fat was the most affected component, it decreased from 36.8 ± 2.4 g/l 2 days before the start of machine milking until 28.7 ± 1.8 g/l in day 10 of training period and returned to its initial value on day 13.

Trial 2: Daily milk yield was 38% higher in machine than hand milking system. Milk secretion rate differed between the 2 milking systems. In the morning (8:00) as well in the afternoon (16:00), lag time was half shorter in machine milking (36.0 ± 6.9 s) than in hand milking (58.0 ± 4.0 s). However, milking time was longer in machine than in hand milking and ranged from 4.2 to 4.8 min and 2.6 to 3.2 min, respectively. Physical parameters of milk had higher values in machine than in hand milking system. However, in the morning, milk density was comparable between the 2 milking systems.

Key words: Behaviour, maghrebi dairy camel, machine/hand milking systems

In Tunisia, there are some 1,00,000 Maghrebi camels (*Camelus dromedarius*) reared in arid and desert regions to produce essentially meat (Hammadi, 2003). Milk is considered a secondary product and reserved for calves and shepherds. Under these conditions, daily milk yield is 2.0 L on average (El-Hatmi *et al,* 2004). However, camel's milk is traditionally used by nomadic people for human nutrition and therapeutic purposes (Agrawal *et al,* 2002).

Previous studies showed that machine milking of camels was more efficient in collecting milk than hand milking, even if the dams were difficult to adapt to the machine-milking procedures (Hammadi *et al,* 2009). As in many other species, the milk ejection reflex in camels is related to the expression of maternal behaviour. The transition from suckling to milking is improved by milking 2 teats while the calf is suckling the 2 others. In contrast, alveolar milk ejection in cows is induced by endogenous oxytocin that is released in response to tactile teat stimulation by the calf, hand, or milking machine (Bruckmaier, 2005).

One key activity in milking parlour in dairy species is individual dam milking time. In the time and motion paradigm, parlour performance is determined

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by work routine time; performance, in terms of dam throughput, increases as work routine time decreases. Although milking time is not an element of work routine time, it influences parlour performance indirectly through its influence on operator idle time. Operator idle time, a key component of work routine time, is lengthened when operators delay the exit of dams from the parlour side while waiting for the next group, which increases milking time (Armstrong and Quick, 1986; Thomas *et al,* 1993).

This study is aimed to investigate the training period and the short time effects of machine milking on milk yield and milk composition in Tunisian Maghrebi camels reared in intensive system.

Materials and Methods

Animals and feeding

Six healthy Maghrebi dairy camels (10.8 ± 5.0 yr of age; 436 ± 36 kg BW) from the experimental farm of the Arid Regions Institute (IRA, Médenine, Tunisia) at the mid of lactation (20 ± 3 weeks; 5.1 ± 1.3 l/d) were followed up during 4 weeks.

At the beginning of the study, dams were well trained to hand milking during 2 months and never used in machine milking system. They were group penned in loose stalls (20 m2/camel) and exercise area throughout the experiment. Daily ration per animal consisted of a forage mixture made of 5 kg of alfalfa hay (DM, 89.6%; on CM basis; and CP, 14.8%; NDF, 42.2%; on DM basis), and 4 kg of oat hay (DM, 91.8%; on CM basis; and CP, 6.2%; NDF, 68.4%; on DM basis), supplemented with 2 kg of a commercial concentrate (DM, 92.8%; on CM basis; CP, 20.6%; on DM basis). Ad libitum access to clean water was ensured.

Experimental design and parameters studied

Two trials were carried out in this study to assess the camel training period for machine milking and the short time effects of machine milking vs. hand milking on milk yield and milk composition.

Trial 1. *Training period for machine milking:* Before the training period for machine milking, camels were hand-milked twice (08:00 and 16:00 hrs) during 2 weeks in a place close to the enclosure reserved for machine milking. Four days prior to start of the experiment, the milking machine was run at the same time as manual milking to adapt the camels to the noise. Camels were hand-milked only once (morning) the day before being machine-milked. The storage of milk in the udder 24 h after hand-milking increases mammary pressures and may encourage the camel to be milked.

On the first day of machine milking, the camel is forced to enter the restraining box for machine milking twice a day (8 am and 4 pm). An i.v. injection of oxytocin (10 IU/camel) was given to each camel before milking to allow a complete udder emptying. The first day of the machine milking coincides with weaning of the calves. During the training period, animals were observed and samples of milk were taken every 2 days during 2 weeks. Milk production, milk composition, lag time and milking time were individually recorded.

Trial 2. *Effects of machine milking on milk yield and milk composition:*

In trial 2, camels used in trial 1 were monitored during 2 successive weeks; in the first week these were hand-milked twice a day (8 a.m. and 4 p.m.) and in the second week, these were machine-milked at the same frequency. In machine milking system, dams were introduced individually using a restraining stall and a portable milking machine (Agromilk, Agro-service, Tunis, Tunisia). The milking machine was set at 48 kPa, 60 pulses/min, and 60:40 pulsation ratio (Fig 1). The milking routine included teat washing and drying, oxytocin i.v. injection, machine milking, machine stripping, and teat dipping (Polycide, Laboratoires Interchem, Tunis, Tunisia).

In hand milking system, milk let-down was induced by allowing the calf to suckle only the 2 right teats. The two left teats were manually milked by one qualified person, and total accumulated milk in mammary gland is estimated to be twice the collected quantity.

Milk yield, physicochemical characteristics, lag time and milking time were individually recorded of each milking system, for both morning and afternoon milking. In hand milking, the lag time was defined as the time from start of calf tactile teat stimulation until onset of milk ejection, but in machine milking, it was as the time from injection of oxytocin until onset of milk ejection. Milking time was the period between the start of calf tactile teat stimulation or oxytocin injection and the end of milking.

Sampling and physicochemical analysis

In trial 1, total solids, protein, fat and ash in milk were analysed. After milking, two samples (50 ml) were taken from the individual total milk, refrigerated (4°C) and transported to the laboratory for chemical analysis. Total milk solids and ash were analysed by gravimetry. Milk protein was determined by spectrophotometer using the Bradford method (Bradford, 1976) and fat was determined by

Fig 1. Machine milking in a camel.

butyrometers using the Neusal method (Wangoh and Farah, 2004).

In trial 2, a third sample of 500 ml was used immediately after milking of each camel to determine milk pH, density and titrable acidity. Milk pH was measured with a pH meter. Density was assessed by using a thermolacto-densimeter. The titratable acidity (°D) was obtained by titrating 100 ml of milk with N/9 NaOH, using phenolpthalein as the indicator.

Statistical analysis

Data were statistically analysed by the Proc mixed procedure of SAS (SAS version 9.0, SAS Inst. Inc., Cary, NC). In trial 1, the model included the general mean, the fixed effects of training days and the random effects of animals (1 to 6), their interactions and the residual error. In trial 2, the model included the general mean, the fixed effects of milking types (Hand and machine) and milking times (8:00 and 16:00 hrs), the random effects of animals (1 to 6), their interactions and the residual error. Differences between means were determined with the Duncan test ($P<0.05$). Results are presented in least squares means ± SE.

Results

Camel behaviour, milk yield and milk composition during training period

On the first day of machine milking, the camels refused to enter the milking box. Once forced to enter, the camel was constrained between the bars of the box and attached to the hock. Milking began when the camel became relatively calmer after about 10 to 20 min. The start of milking increased the aggressiveness of the camel, which tended to escape the restraining box, foot-stepped on the floor, shuddered, urinated and defecated frequently and there was even incidence of diarrhoea. In order to calm the camel, the person charge of milking continuously massaged her udder. Subsequently, an intravenous injection of oxytocin was given which caused milk ejection and relaxation of the camel. In the first day, the total time between the entry to and the exit from the milking enclosure of the camel averaged about 40 min. Over days of training, the animals become less hostile and the total time between entering and exiting did not exceed 15 min. It should be noted that older camels (>12 years) were quieter and easier to train than younger ones. The lag time, after oxytocin injection, did not change and averaged 29.6 ± 3.0 s. Nevertheless, milking time increased ($P<0.05$) with the change of the milk production and averaged 7.5 ± 0.4 min and 9.4 ± 0.6 min, during the first and the second week, respectively. However, during training it was noticed that the camel was more and more accustomed to the presence of milkers and to the noise of the machine.

Changes in the volume of milk yield during training camels for machine milking are shown in fig 2. On the 2nd day of machine milking, daily milk yield was slightly decreased to 5.02 ± 0.22 l compared to the production (5.33 ± 0.71 l) of day (-2) before the start of machine milking. This production increased to reach 6.51 ± 0.35 l in day 6 and 7.48 ± 0.52 l in day 13 of training. In the second week of the training period,

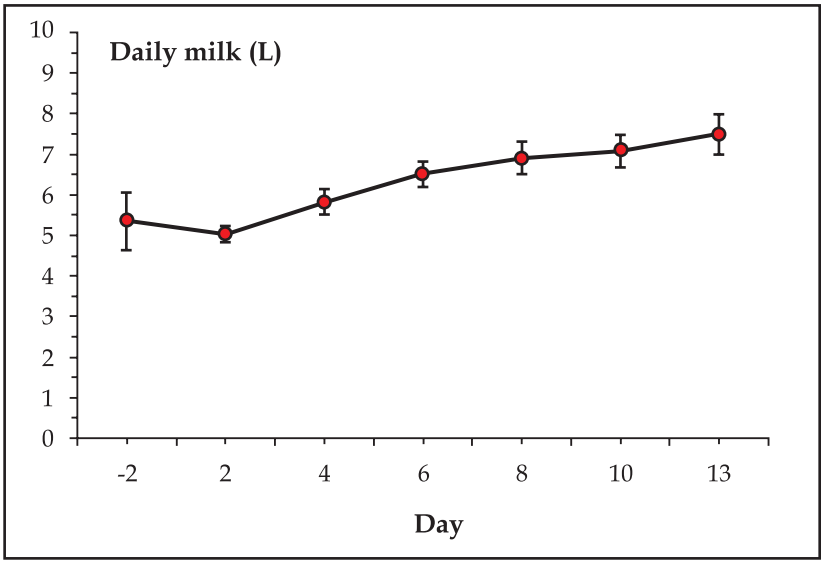

Fig 2. Changes of daily milk yield during training period for machine milking.

no difference was observed between the daily milk yield (P>0.05).

Changes in milk composition during training camels for machine milking are shown in table 1. Total milk solids, protein and ash contents did not vary (P>0.05) and they averaged 115.6 ± 1.4, 23.1 ± 0.5 and 8.5 ± 0.1 g/l, respectively. Milk fat was the most affected (P<0.05) component during training period. It decreased from 36.8 ± 2.4 g/l 2 days before the start of machine milking to 28.7 ± 1.8 g/l on day 10 of training period before returning to its initial value on day 13 (Table 1).

Comparison between machine and hand milking on milk yield and milk composition

Changes in the volume of milk yield and milk composition, according to the time (8:00, 16:00 hrs) and type milking (hand, machine) are shown in table 2. Daily milk yield was 38% higher (P<0.05) in machine than hand milking system; it averaged 7.28 ± 0.33 and 5.29 ± 0.53 L, respectively. Ratios between morning and afternoon milk were approximately 58:42 and 61:39 in hand and machine milking system, respectively. Milk secretion rate differed (P<0.05) between the 2 milking systems. After a 16 h interval between milking sessions (morning sample), milk secretion rate was 195 ± 22 and 278 ± 14 ml/h for hand and machine milking, respectively. For afternoon milking (interval of 8 h), milk secretion was 271 ± 25 and 353 ± 17 ml/h, respectively. In the morning (8:00) as well in the afternoon (16:00), lag time was half shorter (P<0.001) in machine milking (36.0 ± 6.9 s) than in hand milking (58.0 ± 4.0 s). However, milking time was longer (P<0.05) in machine than in hand milking. This time varied between 4.2 to 4.8 min and 2.6 and 3.2 min, respectively.

In general, physical parameters of milk were higher (P<0.01) in machine than in hand milking system. However, in the morning, milk density was comparable (P>0.05) between the 2 milking systems (table 2). Total solids and mineral contents were higher (P<0.05) in machine than in hand milking, but fat and protein contents were comparable (P>0.05). The mean for fat and protein contents in milk were 33.7 ± 1.7 and 23.6 ± 1.0 g/l, respectively. Secretion rate of total solids, fat, protein and ash contents were highest in machine than in hand milking system (data not shown). The difference in secretion rate was more important in 8-hour-milking intervals.

Table 1. Milk composition (g/l) of dairy camels during training period for machine milking.

Day	Milk composition			
	Total solids	Fat	Protein	Ash
-2*	112.8 ± 4.9	36.8 ± 2.4[a]	25.4 ± 1.9	8.2 ± 0.1
2	112.3 ± 2.8	32.4 ± 1.4[ab]	24.2 ± 1.1	8.5 ± 0.1
4	114.2 ± 3.0	31.9 ± 2.4[ab]	22.7 ± 1.1	8.5 ± 0.1
6	112.7 ± 2.9	32.9 ± 1.7[ab]	23.4 ± 0.9	8.4 ± 0.1
8	116.7 ± 4.1	33.3 ± 2.7[ab]	23.3 ± 1.7	8.4 ± 0.2
10	118.3 ± 3.6	28.7 ± 1.8[b]	22.4 ± 0.9	8.5 ± 0.1
13	119.8 ± 3.6	37.5 ± 1.6[a]	22.7 ± 2.0	8.5 ± 0.1

*: 2 days before the start of machine milking.

[a,b]: Different letters in the same column indicate significant differences at P<0.05.

Discussion

While dams refuse to enter the containment box in the first days of machine milking, like many other domesticated species such as mare (Caroprese *et al,* 2007) and buffalo (Cavallina *et al,* 2008), camel can be trained for different procedures including entering the parlour and milking. Our results in dams used in small scale milking system confirm studies previously reported by Juhasz and Nagy (2008) in dairy camels used on large scale. These authors

Table 2. Milk yield and milk composition (g/l) of dairy camels subjected to hand milking (HM) and machine milking (MM) systems.

	Morning (8.00)		Afternoon (16.00)	
	HM	MM	HM	MM
Milk yield, L	3.12 ± 0.34[b]	4.45 ± 0.22[a]	2.17 ± 0.2[b]	2.83 ± 0.13[a]
pH	6.40 ± 0.01[b]	6.52 ± 0.01[a]	6.31 ± 0.01[b]	6.46 ± 0.02[a]
Acidity, °D	16.9 ± 0.2[b]	18.4 ± 0.3[a]	17.91 ± 0.25[b]	18.08 ± 0.37[a]
Density	1.0283 ± 0.0006	1.0276 ± 0.0001	1.0237 ± 0.0004[b]	1.0259 ± 0.0004[a]
Total solids	104.9 ± 3.1[b]	114.3 ± 3.1[a]	121.3 ± 3.6	126.8 ± 2.8
Fat	23.8 ± 1.7	27.2 ± 1.8	48.3 ± 2.4	42.6 ± 2.1
Protein	23.5 ± 0.9	22.0 ± 1.1	26.1 ± 1.5	23.4 ± 1.2
Ash	8.3 ± 0.1[b]	8.6 ± 0.1[a]	8.1 ± 0.1[b]	8.4 ± 0.1[a]

[a–b]: In each row, means with different superscript letters are significantly different (P<0.05).

indicate that the training of a milking camel takes 2 to 4 weeks depending on the background of the animal. Multiparous dams are quieter and easier to train than primiparous confirming observations in buffaloes (Cavallina *et al,* 2008).

It has been documented that lag time in dairy cows depend on degree on udder filling (Bruckmaier, 2005) which varied with interval between milking, stages of lactation and udder cistern volume. In fact, camels have limited cistern volume compared to cows (Baimukanov, 1974, Ayadi *et al,* 2009), which could reduce lag time in normal conditions. In our study and after oxytocin injection, this parameter did not change and was approximately half a minute. Nevertheless, milking time, which increased with the change of milk production, lasts about 10 min. This parameter could be reduced by half (case of trial 2) if camels are well trained or even more as reported by Wernery *et al* (2004) in dromedaries (126.9 ± 41.1 sec.).

In the morning (8:00) as well in the afternoon (16:00 hrs), lag time was shorter by half in machine milking than in hand milking. It appears that about 1 min of calf tactile stimulation is necessary to elicit oxytocin secretion in dams. This value is comparable to that observed in dairy cows (Ruegg *et al,* 2000). In fact, lag time from the start of tactile teat stimulation until full milk ejection depends on the degree of udder filling, which, in turn, depends on the interval between milking sessions and the stage of lactation (Bruckmaier, 2001). Nevertheless, the injection of oxytocin (10 IU) considerably reduces the lag time by half. This lag between oxytocin injection and milk ejection is accounted for by the time required to transport the hormone to the udder and for the alveoli to fully contract. Without injection of oxytocin, the stimulation time to induce milk let-down in camel milked with machine system is around 2 min (Juhasz and Nagy, 2008). However, milking time was longer in machine than in hand milking. This time ranged from 4 to 5 min and 2 to 4 min, respectively. The development of a large-scale milking system should take into consideration these 2 parameters with the morphological characteristics of dams. In dairy cow, Price *et al* (1972) assumed that milking time is normally distributed and averaged 5.5 ± 2.67 min. Bickelt *et al* (1972) predicted milking time based on a gamma distribution with a mean of 4.17 min per cow. Micke and Appleman (1973) based their milking time prediction on means of 4.25 min per cow for fast milking or low yielding herds and 4.95 min per cow for slow milking or high yielding herds. Studies have indicated that the 2 largest sources of variation in milking time are differences between cows and differences among observations for the same cow in the same lactation (Thomas *et al,* 1993). Percentage of variation that was due to differences among cows was estimated to account for 49.8 to 55.7% of the total variation in milking time even after adjustment for milk yield differences (Smith *et al,* 1974). In a technical note of the Kingshay Farming Trust, milking time ranges from 5 to 9 min for 10 and 30 litres milk yield, respectively. Other important sources of variation in milking time included vacuum and pulsation ratio (Rasmussen and Madsen, 2000). Milking time decreased with increasing vacuum and wider pulsation ratio (Thomas *et al,* 1993; O'Callaghan and Gleeson, 2004).

Daily milk yield was 38% higher in machine than hand milking system. Furthermore, in hand milking system, only half of the produced milk could be harvested since the 2 right teats were reserved for calf. The milk accumulated in the mammary gland is more important in the morning than in the afternoon. This could be explained by the time elapsed after the last milking (Ayadi *et al,* 2009). The pH value of milk was higher in machine than in hand milking system but it is still within the ranges reported in literature (Hammadi *et al,* 2007; Jrad, 2007). The overall mean value is 6.40 and therefore camel's milk is more acidic than fresh cow's milk which has a pH of 6.7 (O'Mahony, 1988).

The composition of camel milk has been reviewed by Konuspayeva *et al* (2009) who concluded that the variability of camel milk composition clearly depended on the geographical origin and year of publication of the data. In our study, total solids and ash contents were higher in machine than in hand milking system but values are in the range of published data from North African region. Except for ash content, which was positively correlated to milking interval, all other gross components of milk decreased as milking interval increased. Milk fat was the component most affected by milking interval, decreasing by 51% and 36% between the 8 and 16 h milking intervals, respectively in machine and hand milking systems. Our results support those of Ayadi *et al* (2009), who reported that milk fat was the component most affected by milking interval, decreasing 37% between 8 and 24 h milking intervals.

Fat and protein contents of the camel milk in our results were lower than the values reported by Ohri and Joshi (1961), Elamin and Wilcox (1992)

and Ayadi *et al* (2009) but within the range of those reported by Alshaikh and Salah (1994), El-Hatmi *et al* (2004) and Haddadin *et al* (2007), which could be a consequence of individual, breed, and management differences, as well as of milking conditions (e.g., using oxytocin in our study).

In conclusion, machine milking is a practical technology to improve the harvested camel milk in intensive production system and without altering chemical composition of milk and health of dams. However, for the well-being of camels more research in behaviour and anatomo-physiological characteristics of this species are necessary.

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