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A New Approach in the Evaluation of Dairy Camels: Using Test Day Milk and Morphometric Records

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Abstract: In the case of camels, there is little data in the literature on the relationship between body building features and the evaluation of milk yield. In the last decade, a rising interest in camel milk has been observed due to its nutritional and health-promoting properties, resulting in a growing market demand. Despite the remarkable importance of camels, very little improvement in camel breeding and selection for dairy purposes has been achieved. The current study aimed to provide a practical approach to the evaluation of dairy dromedaries based on test day milk and morphometric records. A total of 62 Sindi dairy camels were evaluated and 4176 daily milk records were registered in February, March, April, and May 2021. She-camels were milked twice per day (at morning and evening) by hand before calf sucking. The farming system was intensive with two times feeding. Three measurements had the highest scores in assessing: udder, teats distance and placement, and teats size, which included 45 out of 100 scores. Test day milk records were analysed using a simple repeatability model with two random effects. The range of daily milk yields was estimated between 0.1 to 8.70 kg. The mean of body scores was 77.19 (CI = 74.19–80.19). Daily milk yields moderately correlated with body score (r = +0.27). Additionally, udder circumference and abdomen girth were correlated to milk production. Using test day milk records in breeding programs can be appropriate for the selection and replacement of she-camels, but due to difficulties in accessing these data, using morphometric data is a good criterion for the evaluation of dromedaries in extensive systems.

Keywords: dairy camel; milk production; test day record; body score

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1. Introduction

Camels have fewer nutritional requirements than other dairy animals [1]. They are kept in the arid and semi-arid regions of the Middle East, Asia and North Africa for milk production. *Camelus bactrianus* and *Camelus dromedarius* are two distinctive and recognizable livestock species and the latter is commonly used for dairy [2–4]. In 2010, about 25.2 million camels produced more than 2.12 million tons of milk [5]. The highest population of dromedaries are found in northeast African countries, including Somalia, Ethiopia, and Sudan, within a latitudinal zone laying between 33° N and 40° S [6,7]. This species plays a key role in economics, especially for people in arid, semi-arid, and desert areas. So far, camels have not been explicitly selected for milk production, and there has been no significant genetic improvement. High variance in milk production, both in ecotypes and breeds, provides a reasonable basis for genetic selection and improvement [8]. On the other hand, it is difficult to record the daily milk yield of each camel, since they are not only principally kept on extensive pasture managements [9], but also hand milked in traditional and semi-intensive farming systems accompanied by a calf, as it is the common practice with camels [10]. The factors that affect milk production mostly include genetics, age, parity, lactation stage, nutrition, management, calving month, and day length. However, the exact role of various elements in camels has not been thoroughly studied, and our understanding of their physiological processes is minimal [9]. The issue of genetic evaluation of dairy cows using test day models (TDM) has been studied by various researchers [11]. There are several benefits to using TDM, including more accurate adjustment of temporary environmental effects in the TDM record, avoidance of extensive records for elimination ranges, and the possibility of genetic evaluation for continued lactation. Many review studies have examined almost all aspects of the use of TDM in the genetic evaluation of dairy cows [12] and even this approach in small dairy ruminants such as goats [13] and sheep [14] is well developed. Unfortunately, in the case of camels, the traditional breeding method and non-breeding programs have not made any progress in using milk test day records for the genetic evaluation of this species, and despite the importance of this issue, it has been neglected. Therefore, the current study aimed to provide a practical approach to the evaluation of dromedary dairy camels based on the test day milk and morphometric records.

2. Materials and Methods

The present study was conducted at a dairy intensive system farm (located in South Khorasan, Birjand, Iran (latitude and longitude, 37.42° N and 57.31° E). A total of 62 Sindi dairy camels of Pakistani origin (25 she-camels from Eastern and 37 she-camels from Western Pakistan) were evaluated in 2021. The mean age of she-camels was 11.5 years, and the age range was between 9 and 14 years. A total of 4176 daily milk records of she-camels were registered in February, March, April, and May 2021. She-camels were milked twice per day (once in the morning and once in the evening) by hand before calf sucking, The milking worker kept about one kilogram of each milking for the calf to consume. The she-camels were fed twice a day. The daily diet per she-camel included: 2.7 kg Alfalfa hay, 2 kg *Alhagi camelorum*, 2 kg Wheat straw, 3.4 kg Concentrate, 0.5 kg Barely grain, 0.5 kg Wheat barn, and 0.1 kg Salt. The daily milk yields were recorded from 303.25 ± 63.13 to 457.25 ± 63.14 days in milk (DIM). Thirteen measurements of body, including body length (cm), neck length (cm), neck girth (cm), hand length (cm), leg length (cm), rump height (cm), hump height (cm), withers height (cm), chest girth (cm), chest width (cm), abdomen girth (cm), chest depth (cm), rump width (cm), tail length (cm), udder height (cm), and udder circumference (cm), were recorded. Twenty-four measurements were used to evaluate the body score, considering a maximum score of 100. The measurements included color (one score), hair distribution (one score), height at withers (four scores), body weight (five scores), head size (two scores), neck (two scores), front legs front view (three scores), front legs side view (three scores), chest width (four scores), chest girth (four scores), chest callosity (two scores), hump (one score), lumbar area angle (two scores), rump width (three scores), rear legs rear view (three scores), rear legs side view (three scores), feet (two scores), fetlocks (four scores), tail (three scores), udder (25 scores), teats distance between each other (10 scores) and placement (10 scores). The relationship between milk production and body scores and morphometric records were assessed using Pearson correlation coefficients. The independent samples t- test was used to compare camels' performance of east and West Pakistan. The equality of variance was evaluated using Levene's test. Test day milk records were analyzed using the simple repeatability model with two random effects, including additive genetic effect and permanent environment effect. The month of lactation and the geographical origin of the she-camel was considered as fixed effects. Camel age, mating age, body score, and body weight were considered as covariates. The repeatability model is as follows:

$$Y = Xb + Za + Wc + e$$

Y: Vector of test day milk records;
b: Regression coefficient of fixed effects;
a: Regression coefficients of additive random effects;
c: Regression coefficients of permanent environmental effects;
e: Residual effects;

and X, Z, and W are the matrices of coefficients linking observations to fixed effects, random additive genetic effects, and permanent environment effect, respectively. The maximum likelihood Log, AIC (Akaike's Information Criteria), BIC (Bayesian Information Criteria), and Penalty Factor value were used for the evaluation of the model. We used WOMBAT and SPSS software to analyze the data.

3. Results

3.1. Milk Yields

The average daily milk yields from ten to fifteen months after calving were 2.55 kg ± 1.23. The range of daily milk yields was estimated between 0.1 to 8.70 kg. The mean of morning daily milk yields (1.26 kg ± 1.02) was significantly higher than evening yields (0.76 kg ± 0.68; $p < 0.05$). Milk production between February and March 2021 was more than between April and May 2021 (Table 1). The average daily milk yields of she-camels originating in east Pakistani states was 2.83 kg ± 1.37, which was higher than West Pakistan camels (2.25 kg ± 1.05; $p < 0.05$). The model estimate for camels originating in the eastern states of Pakistan was favourable compared to the western Pakistani samples (Table 1).

Table 1. The mean of daily milk yields, standard deviation, coefficient of variation, number of records, and estimated value of repeatability model for recording months and geographical origins of she-camels.

Recording Months	DMY * (kg)	SD	N Records	CV	E-Value
Recording month					
February 2021	2.68	1.37	1212	0.51	0.36
March 2021	2.87	1.05	1131	0.36	0.36
April 2021	2.10	1.20	1102	0.56	−0.27
May 2021	2.52	1.20	573	0.47	−0.44
Geographical origin					
East Pakistan	2.83	1.35	2093	0.47	0.31
West Pakistan	2.25	1.05	1925	0.45	−0.31

* DMY (daily milk yield), SD (standard deviation), N records (number of records), CV (coefficient of variation), E-value (estimated value).

The additive genetics and permanent environment effects were estimated for each camel. Due to the lack of pedigree matrix and only one set of lactation data, these values were equal in each camel and were distributed with mean = 0 and SD = ±0.36. The maximum likelihood Log, AIC, BIC, and Penalty Factor value were −1663.416, −1666.416, −1675.862, and 4.14, respectively. The correlation and regression coefficient between the daily milk yields and model expected values was 0.68 and 0.48. The daily milk yields distributed rather normally, so that the coefficient of skewness and kurtosis of residuals of the model were 0.17 ± 0.039 and 1.23 ± 0.07.

3.2. Milk Yield and Body Scores

The mean of body scores was 77.19 (CI (Confidence Interval), =74.19–80.19). On the other hand, 31.15% of she-camels scored range 50 to 70, also 46.52% scored between 70 and 90, and 16.39% scored higher than 90. The camels' body scores of East Pakistani camels

(84.76 ± 6.60) were higher than West Pakistani camels (77.64 ± 11.61; $p < 0.05$). Daily milk yields moderately correlated with body score (r = +0.27; $p < 0.05$).

3.3. Milk Yield and Correlated Morphometric Records

Results showed that udder circumference and abdominal girth were rather correlated to milk production (r = 0.33 and 0.30, respectively; $p < 0.05$) (Table 2). Udder depth and circumference were highly correlated (r = +0.72). Additionally, udder circumference was moderately correlated to rump height (r = +0.37; $p < 0.05$). Additionally, body length, hump height, and abdomen girth had a positive correlation with udder circumference and depth ($p < 0.05$). Wither height was correlated with udder circumference (r = + 0.44); $p < 0.05$). The udder circumference of eastern Pakistani dromedaries (71.13 cm ±12.14) was more than the western ones (62.67 cm ± 11.41; $p < 0.05$) (Table 3). Additionally, the udder depth in camels of eastern origin in Pakistan (24.08 cm ± 4.42) was higher than the camels of western origin (22.29 cm ± 3.83), although this difference was not significant (Table 3; $p > 0.05$). The mean whither height of eastern Pakistani camels was 10 cm more than the rest ($p < 0.05$). The body length and chest girth of East Pakistan's camels were longer ($p < 0.05$).

Table 2. Correlation coefficients among body measurements (cm) and daily milk yield (kg).

	DMY	BL	NL	NG	HL	FL	WH	HH	RH	ChG	GW	AG	ChD	RW	TL	UD	UC
DMY	1.00	0.04	0.02	−0.05	0.12	0.13	0.01	0.03	0.00	0.00	−0.06	0.30 *	0.19	−0.05	0.06	0.23	0.33 *
BL		1.00	0.45 **	0.44 **	−0.09	0.02	0.10	0.37 **	0.38 **	0.51 **	0.16	0.20	0.32 **	−0.02	0.23	0.27 *	0.27 *
NL			1.00	0.35 **	−0.14	0.18	0.25	0.44 **	0.54 **	0.48 **	0.29 *	0.25 *	0.19	0.18	0.06	0.19	0.12
NG				1.00	0.13	−0.07	0.38 **	0.34 **	0.39 **	0.41 **	0.28 *	0.16	0.14	0.24	0.32 **	0.10	0.09
HL					1.00	0.04	0.12	−0.16	0.01	−0.07	0.25 *	0.06	0.01	0.02	0.04	0.22	0.32 *
FL						1.00	0.21	0.24	0.32 *	−0.11	−0.02	−0.05	−0.18	0.20	−0.08	0.04	0.21
WH							1.00	0.52 **	0.64 **	0.39 **	0.23	0.26 *	−0.01	0.26 *	0.04	0.25	0.44 **
HH								1.00	0.51 **	0.46 **	0.12	0.24	0.02	0.22	0.06	0.270 *	0.35 **
RH									1.00	0.51 **	0.25	0.31 *	0.12	0.19	0.25	0.20	0.37 **
ChG										1.00	0.33 **	0.43 **	0.27 *	0.20	0.24	0.09	0.25
GW											1.00	0.29 *	0.27 *	0.33 **	0.30 *	−0.07	0.15
AG												1.00	0.29 *	−0.03	0.22	0.276 *	0.41 **
ChD													1.00	−0.02	0.16	0.260 *	0.22
RW														1.00	0.10	−0.07	0.15
TL															1.00	0.00	0.22
UD																1.00	0.72 **
UC																	1.00

Daily Milk Yield (DMY), Body Length (BL), Neck Length (NL), Neck Girth (NG), Hand Length (HL), Foot Length (FL), Whither Height (WH), Hump Height (HH), Rump Height (RH), Chest Girth (ChG), Chest Width (GW), Abdomen Girth (AG), Chest Depth (ChD), Rump Width (RW), Tail Length (TL), Udder Depth (UD), Udder Circumference (UC). * p-value < 0.05, ** p-value < 0.01.

Table 3. Daily milk yields (DMY), body scores, and morphometric records of Western and Eastern Pakistani dromedaries.

Item	Geographical Origin	Mean ± SD	t Value	*p*-Value
DMY (kg)	E.P [1]	2.83 ± 1.37	15.59	0.00
	W.P	2.25 ± 1.05		
Body Scores	E.P	84.76 ± 6.60	2.65	0.01
	W.P	77.64 ± 11.61		
Udder Depth (cm)	E.P	24.08 ± 4.41	1.62	0.12
	W.P	22.29 ± 3.83		
Udder Circumference (cm)	E.P	71.13 ± 12.14	2.64	0.01
	W.P	62.67 ± 11.42		

Table 3. *Cont.*

Item	Geographical Origin	Mean ± SD	t Value	*p*-Value
Hump Height (cm)	E.P	209.25 ± 11.84	0.14	0.88
	W.P	208.78 ± 11.96		
Rump Height (cm)	E.P	182.70 ± 11.28	2.27	0.02
	W.P	176.18 ± 10.67		
Body Length (cm)	E.P	159.87 ± 7.46	2.43	0.01
	W.P	154.10 ± 9.88		
Neck Length (cm)	E.P	91.50 ± 7.95	1.52	0.13
	W.P	88.10 ±8.79		
Neck Girth (cm)	E.P	77.08 ± 5.92	1.85	0.06
	W.P	74.40 ± 5.24		
Whither Height (cm)	E.P	189.54 ± 10.86	3.31	0.00
	W.P	179.29 ± 12.33		
Chest Girth (cm)	E.P	213.95 ± 7.93	3.29	0.00
	W.P	206.97 ± 8.18		
Foot Length (cm)	E.P	157.95 ±10.36	0.18	0.83
	W.P	158.83 ± 21.53		
Rump Width (cm)	E.P	40.25 ± 3.01	1.75	0.08
	W.P	38.70 ± 3.58		

[1] E.P: East Pakistan, W.P: West Pakistan.

4. Discussion

4.1. Milk Yields

Due to the differences in measurement methods, we were unable to compare several current studies published on milk production in dromedaries. Some reports are presented in Table 4.

Table 4. Some reports of milk production in dromedaries.

Authors, Publication Year	Reported Milk Production
Mehta et al. (2015) [15]	The average daily milk yield of Bikaneri, Kachchhi, and Mewari breeds of 2.7 ± 0.05, 3.2 ± 0.07, and 2.6 ± 0.08, respectively
Faraz et al. (2018) [16]	Daily milk yield of Marecha camels in the Thal deserts of Punjab, Pakistan was 5.62 kg in extensive and rangeland systems
Khan and Iqbal (2001) [17]	A wide range of 3.5 to 40 kg of daily milk yield
Farah and Fisher (2004), Ali et al. (2009), and Ahmad et al. (2010) [18–20]	The daily milk production of 3–10 kg of Pakistani camels
Raziq et al., 2010 [21]	The daily milk production of 10.2 ± 0.43 kg for Kohi dairy camels in Baluchistan, Pakistan
Melaku and Fesha, 2001 [22]	The average daily milk production in extensive and rangeland conditions of Ethiopia of 2.5 L and 4.14, respectively.
Eisa and Mustafa (2011) [23]	Daily milk production range of Sudanese camels between 5 and 10 kg

Table 4. *Cont.*

Authors, Publication Year	Reported Milk Production
Kamoun and Jemmali (2012) [24]	The average daily milk of Tunisian camels as 6.72 ± 2.46 L
Tezera (1998) [25], Kebebew, and Baars (1998) [26]	That East African camels' average daily milk production was 4.5–7.5 L.
Zeleke and Bekele (2002) [27]	The average daily milk production of 1.5–3.1 L in Ethiopian camels in open rangeland conditions
Nagy et al. (2013) [8]	The average daily milk production is 6 ± 0.12 kg in intensive system in the UAE
Faraz et al., 2020 [1]	Average daily milk production of 7.38 L under extensive conditions (Barela breed in Pakistan)

Comparing the results of studies on milk production is not easy due to the lack of a specific standard. Mehta et al. (2015) reported that the time to reach the peak of milk production varies from one month to 12 months in dromedaries [15]. However, milk production depends on genetic origin, environmental conditions, and nutritional management [28]. In the present study, the effect of the production month was also significant and consistent with Mehta et al. (2015) [15]. The authors did not determine the amount of milk sucked by calves in most published articles [28]. On average, the milk consumed by calves is 40% [29]. Lactation length is much varied and reported from 6 to 19 months [28]. The daily milk records of this research belonged to a period of ten to fifteen months in milk and a decreased ratio in milk production was estimated to be 0.01 kg per day. The rate of decrease in milk production per day after peak production in Wood, Cappio, Cobby, and Dhano models was 0.005, 0.003, 0.3, and 0.004, respectively [30]. The rate of decrease in milk production per day after peak production was estimated to be 0.02 to 0.05 using linear models, and 0.03 to 0.05 using nonlinear models [31]. Idrees et al. (2015) reported a daily decrease in milk production of 0.08 after peak milk production [32].

4.2. The Correlation between the Milk Yield and Body Measurements

The correlation between udder measurements and milk production traits has been well investigated in dairy ruminants, but very little is known about camels in this regard [33]. It is well documented that the daily milk yield, the total milk production, and yield at the peak of production are closely correlated to teat circumference and udder depth [33]. Udder morphology and functional traits are the most critical factors determining milk ability of dairy cattle [33] and camels [34]. Many studies have evaluated the correlation between milk yield and morphometric characteristics such as mammary width (r = +0.41) [35], size and shape of udder (r = 0.15–0.22) [36–39], abdominal girth and height of animal (r = 0.06, and 0.07, respectively) [40] in cows. In these findings, the milk production directly correlated with udder morphometric, face length, and cephalic index in Ongole cattle [40]. Bhuiyan et al. (2004), Rana et al. (2010), and Patel et al. (2016) also found positive correlation between milk production and udder measurements [36,41,42]. However, skin fold thickness and tail length had negative correlation with milk yield. These factors were perhaps used in a breeding program in dairy cattle [40]. The morphology of udders and teats are highly heritable [43]. Abdullah et al. (2012) reported a high variation in the length of udders and teats in Saudi Arabia dromedaries [44]. Therefore, camel producers can consider the characteristics and morphology of udders and teats in selecting superior animals [33]. Udder morphology directly affects lactation traits in cows [45], ewes [46], and dairy goats [47]. Although limited information is available on the evaluation of biometric traits and production performance in dairy camels, the findings of the present study show a moderate correlation between daily milk yield and measurements of udder circumference and depth, consistent with the results of Atigui et al. (2021) [33]. Several evaluation models and approaches have been proposed for analyzing test day milk data in dairy cows.

However, there is currently no consensus about the model that best fits the data. In dairy cows, models with different variables in the fixed, additive genetic or random peripheral parts of the model had higher accuracy [48]. Similarly, by inserting different variables in the fixed and random effects in the present study, we expected that the results obtained from the test day milk records to provide reliable results in the evaluation of she-camels.

5. Conclusions

Using test day milk records in breeding programs can be appropriate for the selection and replacement of she-camels, but due to difficulty accessing this data, using morphometric data is a good criterion for the evaluation of dromedaries in extensive systems. We surveyed the correlation between morphometric measurements and milk yields. It is possible to select camels on the basis of appropriate udder and better body scores to increase milk yield. The measurements of udder and abdominal girth can potentially be used in the selection of camels to improve milk production.

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