

Effects of season, parity and stage of lactation on yield, composition and microbial quality of milk from camels raised in Tsabong, Botswana

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Keywords

dromedaries, milk yield, milk composition, microbial contamination, seasonal variation, lactation stage, Botswana

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Summary

Background: Introduced to Botswana in the early 20th century, dromedaries remain little exploited for milk production. In Tsabong, the herd is mainly used for tourism, and no study has yet assessed influencing factors on milk yield or composition. **Aim:** This study was conducted to assess the effects of season, parity, and stage of lactation on the yield, composition, and quality of camel milk at the Tsabong Ecotourism Camel Park. **Methods:** Twenty lactating camels, averaging eight years old and at various lactation stages (early, mid, and late) and parities (2–6), were studied. They browsed freely during the day and received 3 kg of a 1:1 saltbush–sorghum bran supplement at night, with unlimited access to water and salt. Milk yield was measured every three days over six weeks. A total of 560 records were collected during the dry season and 640 during the wet season. Milk samples for chemical and microbiological analysis were collected six times over a two-week period. Data were analysed using SAS for non-balanced data. **Results:** Milk yields were significantly higher during the wet season (1,340 ml/day) than during the dry season (781 ml/day). In the dry season, milk yield decreased as parity increased, while in the wet season, milk yield increased up to the fifth parity before declining. The stage of lactation significantly influenced fat, protein, solids-not-fat (SNF), and density in the dry season. Early lactation milk had higher protein, SNF, and density, while fat content peaked in mid lactation. In the wet season, only the protein content varied significantly across lactation stages. Parity significantly affected titratable acidity, protein, and lactose in the dry season, and protein, lactose, total solids, SNF, and pH in the wet season. The highest values were observed in camels at their second parity during the wet season. Fat and total solids were higher in the wet season overall. Coliform counts were generally higher in samples collected during the wet season. *Salmonella* was detected in 3.42% of dry season samples and 1.7% of wet season samples, highlighting public health concerns. **Conclusions:** These findings highlight the need for improved hygiene during milking and the importance of heat treatment before consumption.

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■ INTRODUCTION

Botswana is an arid country, with over 80% of the total land area classified as drylands and three quarters covered by the Kalahari Desert (Madzwamuse *et al.*, 2007; Crawford, 2016). The mean annual rainfall ranges from over 650 mm in the northeast to less than 250 mm in the southwest; however, rainfall is highly erratic, and the country is subject to periodic droughts (Madzwamuse *et al.*, 2007). In Botswana, camels are found in Kgalagadi, a district located in the southwestern part of the country and covering a large part of the Kalahari Desert.

Camels were introduced to Botswana at the beginning of the twentieth century, mainly from the Cape of Good Hope, now called Cape Town. The camels of the Cape of Good Hope were initially imported from the Canary Islands in the late 19th century, and later from Egypt and Karachi (then part of Indian territory) (Wilson, 2009). Until replaced by vehicles, the Botswana Police Service used camels for regular patrols in the sandy Kgalagadi District and for postal delivery services between Tshane and Tsabong. The police service continued to use camels on patrols up to the early 1980s and kept them as government property until 2001, when they were handed over to local communities with the intention of developing an ecotourism industry based on camel safaris (Wilson, 2013). Consequently, the Tsabong Ecotourism Camel Park was established in 2005, and it is where the majority of the country's camels are currently kept.

Although camels were introduced to Botswana a long time ago, they have not yet been fully used for food production, particularly milk production, in the country. However, the main reason for keeping camels elsewhere in the world is food production, especially milk production, in addition to their use for transport, meat production, and many other services. The Tsabong camel herd is currently used primarily for tourism (e.g., riding safaris within and around the park) and for entertainment purposes (Seifu *et al.*, 2018). In recent years, communities in the vicinity of the Tsabong Ecotourism Camel Park have started consuming camel milk. The Park sells camel milk to consumers at a price of 40 Pula per litre (around 2.6 EUR). A study by Tselaesele *et al.* (2021), which explored the perceptions and attitudes of local communities in the Kgalagadi District concerning camels, revealed that the communities have a positive attitude towards camels and their products. There are no socio-cultural factors (beliefs) that would hinder the use of camel milk, camel milk products, or raising camels in the Kgalagadi District. Moreover, the people in Kgalagadi District expressed a desire to keep camels for income generation.

A preliminary study based on a single observation of milk samples collected from the Tsabong camel herd showed that daily milk yield of camels in Tsabong ranged from 1.7 to 1.9 litres (Field & Gitao, 2011; Seifu *et al.*, 2019), which is much lower than the milk yield of camels elsewhere in the world. The reported amount of milk for the Tsabong camels was obtained through once-daily milking. Similarly, a study by Makgoeng *et al.* (2018) on milk samples obtained from Tsabong camels in their eighth month of lactation showed average values of fat, protein, total solids, solids-not-fat, pH, titratable acidity, specific gravity and ash contents as $2.0 \pm 0.14\%$, $1.8 \pm 0.19\%$, $12.2 \pm 0.75\%$, $10.2 \pm 0.61\%$, 6.35 ± 0.09 , $0.163 \pm 0.019\%$ lactic acid, 1.027 ± 0.01 and $0.77 \pm 0.13\%$, respectively. This is the only published report on the composition of milk obtained from the Tsabong camel herd.

Several factors have been reported to affect the yield and composition of camel milk, including management practices, stage of lactation, parity, season of calving, feeding, species, breed, age, health of the animal, reproductive status (oestrus, gestation), milking frequency, presence of the calf, method of milking, heat stress, and availability of water (Bekele *et al.*, 2002; Megersa, 2010; Farah, 2011; Nagy & Juhasz, 2016; El-Agamy, 2017; Alhadrami & Faye, 2022; Megersa *et al.*, 2024).

Camels can survive and continue to produce milk during dry seasons when other livestock species struggle to survive. They produce more milk for longer periods (about 12 months of lactation) during droughts than any other domestic animal adapted to arid habitats (Farah *et al.*, 2007; Tefera & Abebe, 2012). Given Botswana's agroecology, which is well suited for camel husbandry, there is a huge potential to develop a camel dairy sector in the country that could contribute substantially towards the national milk supply and produce diverse dairy products based on camel milk for both domestic consumption and export. Yet despite this potential, few attempts have been made to use camels for

food production or other non-food purposes beyond their role in the tourism sector.

To date, no study has been conducted to assess the milk yield of the Tsabong camel herd during the dry and wet seasons. No reports have been published regarding the effects of parity and lactation stage on the yield and composition of milk obtained from the Tsabong camel herd. The objectives of this study were therefore to determine how parity, lactation stage, and season affect the yield and composition of milk from camels raised at the Tsabong Ecotourism Camel Park, and to determine the hygienic quality and safety of camel milk in the study area.

MATERIAL AND METHODS

Description of the study area

The study was conducted in Tsabong, the administrative centre of the Kgalagadi District in southwestern Botswana (Figure 1). The geographical coordinates of Tsabong are $26^{\circ} 3' 0''$ South, $22^{\circ} 27' 0''$ East. The study site is located 520 km from the capital city, Gaborone, and 10 km north of Tsabong town, and comprises a fenced area measuring 4×4 km. The area has sparsely distributed vegetation dominated by *Grewia*, *Senegalia* and *Vachellia* species, along with some grass species (Kgaudi, 2014). Tsabong is the capital of the Kgalagadi South subdistrict, and has 9,471 inhabitants, representing 31.6% of the sub-district's population (Statistics Botswana, 2015).

The winter season (June to August) is dry and cold, with temperatures ranging from 1 to 12 °C. The summer (December to February) is the rainy season, and features temperatures ranging from 28.5 to 35.0 °C. Rainfall occurs from December to March and averages 26 mm per year, ranging from 0.6 to 61 mm per month (Zweistra, 2012). The area is an inland plateau of relatively flat savannah woodland and grassland with an average altitude of 1,000 m. Agriculture, in the form of cattle and game (wildlife) farming, and hunting have historically



Figure 1: Map of Botswana showing the study area Tsabong (also called Tshabong) in Kalahari Desert /// Carte du Botswana indiquant la zone d'étude de Tsabong (également appelée Tshabong) dans le désert du Kalahari

(Source: Wikipedia, <https://commons.wikimedia.org/w/index.php?curid=183918>)

been the main economic activities of the area (Zweistra, 2012). The Kalahari Desert, which covers nearly 70% of the country's land area, is in this region, and the soil is generally sandy and infertile (Batisani, 2010). Arable agriculture is consequently limited.

Experimental animals and management

Twenty lactating camels, averaging 8 years of age, sourced from the Tsabong Ecotourism Camel Park, were used for the experiment. The camels were at different stages (early, mid, late) and numbers (2, 3, 4, 5, 6) of lactations. Camels that were 1–4 months postpartum were grouped under early lactation, those that were 5–7 months postpartum were grouped under mid lactation, and camels that were over 7 months postpartum were grouped under late lactation. At night, the lactating camels were kept in an open kraal and given supplementary feed, while during the day they were allowed to browse as a group within the park. The supplements were provided to the animals at a rate equal to 25% of their total dry matter intake (DMI). The DMI was estimated as 3% of the animal's body weight (400 kg), or 12 kg. Each lactating camel was therefore given every evening 3 kg (12×0.25) of supplementary feed, consisting of a mixture of saltbush (*Atriplex nummularia*) and sorghum bran (1:1). Mineral licks and clean water were provided daily *ad libitum*. All of the camels were managed, fed, and watered in the same way.

Milking and milk sample collection

Camels were milked every three days for six weeks in the morning. Calves were allowed to suckle their dam for two minutes to stimulate milk letdown, and were then separated from the dam to allow milking. All camels were hand milked by their caretakers. Before milking, the camel's teats were washed with clean tap water and dried with a single-use towel.

Camel milk samples were collected six times at two-week interval from 20 individual lactating camels and delivered to the Botswana National Veterinary Laboratory (BNVL) in Sebele, Gaborone, for chemical and microbial analysis. Each time, two separate milk samples (250 ml each) were taken from each animal for chemical and microbiological analyses. During the dry season, a total of 117 raw milk samples were analysed for physicochemical parameters, whereas 119 milk samples were analysed for the determination of microbial quality. During the wet season, a total of 120 camel milk samples were analysed for their physicochemical parameters and microbial quality. The milk samples used for chemical analysis were stored in clean plastic bottles. The camel milk samples used for microbial analysis (250 ml) were stored in separate sterile containers (McCartney bottles). All milk samples were then placed in a cooler box containing ice cubes and transported to the BNVL.

Determination of milk yield

The milk yield of camels was measured and recorded from August to October 2022 during the dry season, and from December 2022 to March 2023 during the wet season. Twenty lactating camels were milked once every three days. The camels were hand milked, and the milk was collected directly into a graduated measuring cylinder. A total of 560 milk samples were used to calculate the daily milk yield of the 20 camels during the dry season, while 640 milk samples were used to calculate milk yield during the wet season.

Analysis of milk composition

The milk samples were analysed in triplicate for fat, protein, lactose, total solids (TS), solids-not-fat (SNF), density, pH and titratable acidity (TA), and freezing point depression (FPD) with Fourier-transform infrared spectroscopy (Saji *et al.*, 2024) using the MilkoScanTM FT1

milk analyser (Foss Electric A/S, Hillerød, Denmark) at the Botswana National Veterinary Laboratory. Equal volumes (50 ml) of milk and diluent solutions were weighed and mixed thoroughly. The sample was heated to 40 °C in a water bath before analysis. The milk sample was then placed in the milk analyser and measurements were taken.

Microbiological analysis

Milk samples for microbial analysis were obtained in duplicate from individual animals at two-week intervals, placed into sterile containers (250 ml), and transported to the laboratory immediately after collection where they were kept at 4 °C overnight pending laboratory analysis. The milk samples were analysed for total viable count using ISO standard 4833-1:2013 (ISO, 2013), for coliform count using ISO standard 4832:2006 (ISO, 2006), and for the presence of *Salmonella* species using ISO standard 6785:2001 (ISO, 2001).

Statistical analysis

The General Linear Model (GLM) procedure (SAS, 2002–2012) for unbalanced data was used to determine the effect of the independent variables (parity, stage of lactation) on milk yield and milk composition. Microbial count data were transformed to $\log_{10}$ values before statistical analysis. When the analysis revealed a significant effect, the probability of difference (PDIF) option in the LSMEANS statement of the GLM procedure of SAS (2002–2012) was used to separate the means. The level of significance was set at $p < 0.05$.

RESULTS

Yield, composition and quality of camel milk during the dry season

The lactation stage showed a significant ($p < 0.05$) effect on the milk yield of camels during the dry season (Table I). The highest milk yield was recorded for early lactation, and late lactation had the lowest yield (Table I). Parity also had a significant ($p < 0.05$) effect on the milk yield of camels during the dry season (Table II). A decrease

Table I: Effect of stage of lactation on daily milk yield (mean $\pm$ SEM) of camels reared at Tsabong Ecotourism Camel Park during the dry season (mean yield of 20 animals) /// *Effet du stade de lactation sur la production laitière quotidienne (moyenne $\pm$ SEM) des chamelles élevées au Tsabong Ecotourism Camel Park pendant la saison sèche (production moyenne de 20 animaux)*

Stage of lactation	Milk yield (mL)
Early (1-4 months)	1160.99 ^a $\pm$ 148.02
Mid (5-7 months)	685.25 ^b $\pm$ 132.92
Late (> 7 months)	596.30 ^b $\pm$ 85.77

Table II: Effect of parity on daily milk yield (mean $\pm$ SEM) of camels reared at Tsabong Ecotourism Camel Park during the dry season (mean yield of 20 animals) /// *Effet de la parité sur la production laitière quotidienne (moyenne $\pm$ SEM) des chamelles élevées au Tsabong Ecotourism Camel Park pendant la saison sèche (production moyenne de 20 animaux)*

Parity	Milk yield (mL)
2	1182.24 ^a $\pm$ 139.15
3	711.21 ^b $\pm$ 122.82
4	759.50 ^b $\pm$ 101.07
5	603.76 ^b $\pm$ 187.77

in milk yield was observed with increasing parity. The highest milk yield was observed for camels in their second parity (Table II).

The stage of lactation had a significant effect ($p < 0.05$) on fat, protein, SNF, and density of camel milk samples during the dry season (Table III). The highest fat content was observed for camels in mid lactation, and the lowest fat content was observed for camels in early lactation (Table III). The protein and SNF contents of milk from camels in the early stage of lactation were much higher, but protein and SNF decreased with advancing lactation (Table III). Milk samples from camels in an early stage of lactation had the highest density (Table III). No significant difference ($p > 0.05$) was observed for TA, lactose, TS, pH, coliform count, and total viable count for milk samples collected from camels during the dry season for the different stages of lactation (Table III).

Parity had a significant effect ($p < 0.05$) on the TA, protein, and lactose contents of camel milk during the dry season (Table IV). Milk samples obtained from camels at their second parity had the highest TA (Table IV). Similarly, milk samples obtained from camels at their second parity had the highest protein content; however, the lowest protein content was observed in milk samples obtained from camels at their third parity (Table IV). On the other hand, the lowest and highest lactose contents were observed in milk samples obtained from camels at their second and third parity, respectively (Table IV). With regard to parity, when the protein content decreased, the lactose content of the milk increased, and vice versa (Table IV).

No significant differences ($p > 0.05$) were observed in the total viable count (TVC) and coliform count (CC) among camel milk samples obtained from the three stages of lactation (Table III), nor among milk samples obtained from camels at different parities (Table IV). Out of the 117 camel milk samples analysed for the determination of microbial quality during the dry season, 4 samples (3.42%) tested positive for *Salmonella* species.

Yield, composition, and quality of camel milk during the wet season

No significant difference ($p > 0.05$) in milk yield was observed across the different stages of lactation during the wet season (Table V). Unlike the dry season, an increase in milk yield was observed with advancing lactation (Table V). The milk yield of camels was much higher during the wet season than during the dry season, especially in mid and late lactations. Parity did not have a significant effect ($p > 0.05$) on the milk yield of camels during the wet season (Table VI). Unlike the dry season, an increase in milk yield was observed with increasing number of parturitions up to the fifth parity. The highest milk yield was observed for camels at their fifth parity during the wet season.

No significant difference ($p > 0.05$) in milk yield was observed between the different stages of lactation. Similarly, no significant difference in milk yield was observed between the different parities. During the wet season, only the protein content showed a significant difference ($p < 0.05$) between milk samples obtained from camels at different stages of lactation (Table VII). No significant difference ($p > 0.05$) was observed for the remaining milk components across the stages of lactation (Table VII). Parity had a significant effect ($p < 0.05$) on the protein, lactose, TS, SNF, and pH levels of camel milk samples obtained during the wet season (Table VIII). The highest protein, lactose, TS, and SNF contents were observed in milk samples obtained from camels at their second parity (Table VIII), and the lowest pH, lactose, and SNF contents were observed in milk samples obtained from camels at their fourth parity (Table VIII). Milk samples obtained from camels at their second and sixth parities showed the highest pH value (Table VIII). The results showed that the fat and TS contents of camel milk during the wet season were much higher than the corresponding values in the dry season. The overall average milk yield and composition of camel milk collected during the wet and dry seasons are reported in Table IX.

Table III: Effect of stage of lactation on composition and microbial quality (mean $\pm$ SEM) of the milk of camels reared at Tsabong Ecotourism Camel Park during the dry season (mean yield of 20 animals) /// *Effet du stade de lactation sur la composition et la qualité microbienne (moyenne $\pm$ SEM) du lait des chamelles élevées au Tsabong Ecotourism Camel Park pendant la saison sèche (rendement moyen de 20 animaux)*

Stage of lactation	TA (%)	Fat (%)	Protein (%)	Lactose (%)	TS (%)	SNF (%)	Density (g/cm ³)	pH	CC (cfu/mL)	TVC (cfu/mL)
Early	0.105 $\pm$ 0.005	3.02 ^a $\pm$ 0.27	2.42 ^a $\pm$ 0.14	4.18 $\pm$ 0.29	10.90 $\pm$ 0.53	7.55 ^a $\pm$ 0.27	1.028 ^a $\pm$ 0.01	6.58 $\pm$ 0.04	0.15 $\pm$ 0.19	2.80 $\pm$ 0.30
Mid	0.095 $\pm$ 0.004	3.74 ^b $\pm$ 0.24	2.10 ^{ab} $\pm$ 0.12	4.31 $\pm$ 0.26	10.69 $\pm$ 0.47	6.89 ^{ab} $\pm$ 0.24	1.026 ^{ab} $\pm$ 0.00	6.52 $\pm$ 0.04	0.08 $\pm$ 0.43	3.36 $\pm$ 0.27
Late	0.105 $\pm$ 0.002	3.14 ^a $\pm$ 0.15	2.06 ^{bc} $\pm$ 0.08	4.26 $\pm$ 0.16	10.06 $\pm$ 0.30	6.83 ^{bc} $\pm$ 0.15	1.026 ^{bc} $\pm$ 0.00	6.49 $\pm$ 0.03	0.07 $\pm$ 0.30	2.85 $\pm$ 0.17

TA = Titratable acidity (%lactic acid); TS = Total solids; SNF = Solids-not-fat; FPD = Freezing point depression; CC = Coliform count; TVC = Total viable count /// TA = Acidité titrable (% d'acide lactique); TS = Matière sèche totale; SNF = Extrait sec dégraissé; FPD = Abaissement du point de congélation; CC = Nombre de coliformes; TVC = Nombre total de bactéries viables

Table IV: Effect of parity on composition and microbial quality (mean $\pm$ SEM) of the milk of camels reared at Tsabong Ecotourism Camel Park during the dry season (mean yield of 20 animals) /// *Effet de la parité sur la composition et la qualité microbienne (moyenne $\pm$ SEM) du lait des chamelles élevées au Tsabong Ecotourism Camel Park pendant la saison sèche (rendement moyen de 20 animaux)*

Parity	TA (%)	Fat (%)	Protein (%)	Lactose (%)	TS (%)	SNF (%)	Density (g/cm ³)	pH	CC (cfu/mL)	TVC (cfu/mL)
2	0.112 ^a $\pm$ 0.004	3.29 $\pm$ 0.274	2.42 ^a $\pm$ 0.13	3.82 ^a $\pm$ 0.26	10.58 $\pm$ 0.48	7.09 $\pm$ 0.25	1.027 $\pm$ 0.001	6.50 $\pm$ 0.04	0.16 $\pm$ 0.10	2.68 $\pm$ 0.28
3	0.099 ^b $\pm$ 0.004	3.21 $\pm$ 0.21	1.99 ^b $\pm$ 0.11	4.72 ^b $\pm$ 0.23	10.11 $\pm$ 0.43	7.01 $\pm$ 0.22	1.026 $\pm$ 0.001	6.53 $\pm$ 0.04	0.06 $\pm$ 0.09	2.99 $\pm$ 0.25
4	0.103 ^{abc} $\pm$ 0.003	3.39 $\pm$ 0.18	2.21 ^{ab} $\pm$ 0.09	4.14 ^{ab} $\pm$ 0.20	10.63 $\pm$ 0.36	7.01 $\pm$ 0.18	1.027 $\pm$ 0.001	6.51 $\pm$ 0.03	0.02 $\pm$ 0.08	3.06 $\pm$ 0.21
5	0.093 ^{cb} $\pm$ 0.006	3.30 $\pm$ 0.34	2.14 ^{ab} $\pm$ 0.18	4.31 ^{ab} $\pm$ 0.37	10.89 $\pm$ 0.67	7.25 $\pm$ 0.34	1.027 $\pm$ 0.001	6.59 $\pm$ 0.06	0.17 $\pm$ 0.15	3.29 $\pm$ 0.39

TA = Titratable acidity (%lactic acid); TS = Total solids; SNF = Solids-not-fat; FPD = Freezing point depression; CC = Coliform count; TVC = Total viable count /// TA = Acidité titrable (% d'acide lactique); TS = Matière sèche totale; SNF = Extrait sec dégraissé; FPD = Abaissement du point de congélation; CC = Nombre de coliformes; TVC = Nombre total de bactéries viables

In the wet season, no significant differences ($p > 0.05$) were observed in TVC and CC among camel milk samples obtained from the three stages of lactation (Table VII), nor among milk samples obtained from camels at different parities (Table VIII). Out of the 120 camel milk samples analysed for the determination of microbial quality during the wet season, 2 samples (1.7%) tested positive for *Salmonella* species.

Table V: Effect of stage of lactation on the daily milk yield (mean $\pm$ SEM) of camels reared at Tsabong Ecotourism Camel Park during the wet season (mean yield of 20 animals) /// *Effet du stade de lactation sur la production laitière quotidienne (moyenne $\pm$ SEM) des chamelles élevées au Tsabong Ecotourism Camel Park pendant la saison des pluies (production moyenne de 20 animaux)*

Stage of lactation	Milk yield (mL)
Early (1-4 months)	1173.52 $\pm$ 171.27
Mid (5-7 months)	1402.81 $\pm$ 282.78
Late (> 7 months)	1475.33 $\pm$ 243.08

Table VII: Effect of stage of lactation on composition and microbial quality (mean $\pm$ SEM) of the milk of camels reared at Tsabong Ecotourism Camel Park during the wet season (mean yield of 20 animals) /// *Effet du stade de lactation sur la composition et la qualité microbienne (moyenne $\pm$ SEM) du lait de chamelles élevées au Tsabong Ecotourism Camel Park pendant la saison humide (rendement moyen de 20 animaux)*

Stage of lactation	TA (%)	Fat (%)	Protein (%)	Lactose (%)	TS (%)	SNF (%)	Density (g/cm ³)	FPD (°C)	pH	CC (cfu/mL)	TVC (cfu/mL)
Early	0.112 $\pm$ 0.002	2.34 $\pm$ 0.15	2.36 ^a $\pm$ 0.06	4.44 $\pm$ 0.07	9.93 $\pm$ 0.21	7.44 $\pm$ 0.13	1.029 $\pm$ 0.47	-0.563 $\pm$ 00	6.41 $\pm$ 0.02	1.42 $\pm$ 0.26	2.79 $\pm$ 0.20
Mid	0.113 $\pm$ 0.003	2.17 $\pm$ 0.24	2.08 ^b $\pm$ 0.10	4.33 $\pm$ 0.12	9.29 $\pm$ 0.34	7.18 $\pm$ 0.21	1.029 $\pm$ 0.77	-0.565 $\pm$ 00	6.35 $\pm$ 0.03	1.61 $\pm$ 0.43	2.77 $\pm$ 0.33
Late	0.115 $\pm$ 0.003	2.42 $\pm$ 0.21	2.26 ^{ab} $\pm$ 0.09	4.44 $\pm$ 0.10	9.89 $\pm$ 0.29	7.35 $\pm$ 0.18	1.029 $\pm$ 0.66	-0.564 $\pm$ 00	6.40 $\pm$ 0.03	1.86 $\pm$ 0.37	3.14 $\pm$ 0.28

TA = Titratable acidity (%lactic acid); TS = Total solids; SNF = Solids-not-fat; FPD = Freezing point depression; CC = Coliform count; TVC = Total viable count /// TA = Acidité titrable (% d'acide lactique); TS = Matière sèche totale; SNF = Extrait sec dégraissé; FPD = Abaissement du point de congélation; CC = Nombre de coliformes; TVC = Nombre total de bactéries viables

Table VIII: Effect of parity on composition and microbial quality (mean $\pm$ SEM) of the milk of camels reared at Tsabong Ecotourism Camel Park during the wet season (mean yield of 20 animals) /// *Effet de la parité sur la composition et la qualité microbienne (moyenne $\pm$ SEM) du lait de chamelles élevées au Tsabong Ecotourism Camel Park pendant la saison humide (rendement moyen sur 20 animaux)*

Parity	TA (%)	Fat (%)	Protein (%)	Lactose (%)	TS (%)	SNF (%)	Density (g/cm ³)	FPD (°C)	pH	CC (cfu/mL)	TVC (cfu/mL)
2	0.113 $\pm$ 0.004	2.67 $\pm$ 0.26	2.42 ^a $\pm$ 0.12	4.58 ^a $\pm$ 0.13	10.57 ^a $\pm$ 0.36	7.87 ^a $\pm$ 0.22	1.030 $\pm$ 0.81	-0.568 $\pm$ 0.002	6.44 ^a $\pm$ 0.03	1.52 $\pm$ 0.45	3.06 $\pm$ 0.35
3	0.113 $\pm$ 0.003	2.16 $\pm$ 0.19	2.13 ^b $\pm$ 0.08	4.29 ^{ab} $\pm$ 0.10	9.30 ^{bc} $\pm$ 0.27	6.99 ^{bc} $\pm$ 0.16	1.029 $\pm$ 0.61	-0.563 $\pm$ 0.001	6.36 ^{ab} $\pm$ 0.04	1.61 $\pm$ 0.34	2.67 $\pm$ 0.26
4	0.113 $\pm$ 0.003	2.29 $\pm$ 0.23	2.19 ^{ab} $\pm$ 0.10	4.15 ^b $\pm$ 0.12	9.34 ^{bc} $\pm$ 0.33	6.98 ^{bc} $\pm$ 0.20	1.029 $\pm$ 0.74	-0.561 $\pm$ 0.001	6.32 ^b $\pm$ 0.03	1.62 $\pm$ 0.41	2.73 $\pm$ 0.32
5	0.118 $\pm$ 0.003	2.28 $\pm$ 0.23	2.30 ^{ab} $\pm$ 0.10	4.42 ^{ab} $\pm$ 0.12	9.72 ^{acb} $\pm$ 0.33	7.46 ^{acb} $\pm$ 0.20	1.031 $\pm$ 0.74	-0.565 $\pm$ 0.001	6.37 ^{ab} $\pm$ 0.03	2.01 $\pm$ 0.41	3.16 $\pm$ 0.32
6	0.112 $\pm$ 0.004	2.13 $\pm$ 0.27	2.14 ^{ab} $\pm$ 0.12	4.55 ^{ac} $\pm$ 0.13	9.59 ^{acb} $\pm$ 0.38	7.31 ^{acb} $\pm$ 0.23	1.029 $\pm$ 0.85	-0.563 $\pm$ 0.002	6.44 ^a $\pm$ 0.04	1.40 $\pm$ 0.48	2.87 $\pm$ 0.37

TA = Titratable acidity (%lactic acid); TS = Total solids; SNF = Solids-not-fat; FPD = Freezing point depression; CC = Coliform count; TVC = Total viable count /// TA = Acidité titrable (% d'acide lactique); TS = Matière sèche totale; SNF = Extrait sec dégraissé; FPD = Abaissement du point de congélation; CC = Nombre de coliformes; TVC = Nombre total de bactéries viables

Table IX: Overall average ($\pm$ SD) yield, composition and microbial counts of camel milk collected during the dry and wet seasons at Tsabong Ecotourism Camel Park /// *Rendement moyen global ($\pm$ SD), composition et nombre de micro-organismes du lait de chamelle collecté pendant les saisons sèche et humide au parc écotouristique de chamelles de Tsabong*

Season	Yield (mL)	TA (%)	Fat (%)	Protein (%)	Lactose (%)	TS (%)	SNF (%)	Density (g/cm ³)	FPD (°C)	pH	CC (cfu/mL)	TVC (cfu/mL)
Dry season	781 $\pm$ 343	0.114 $\pm$ 0.011	2.31 $\pm$ 0.44	2.26 $\pm$ 0.32	4.38 $\pm$ 0.27	9.71 $\pm$ 0.82	7.29 $\pm$ 0.57	1.029 $\pm$ 0.00	-0.563 $\pm$ 0.003	6.39 $\pm$ 0.11	1.63 $\pm$ 1.67	2.88 $\pm$ 1.26
Wet season	1340 $\pm$ 458	0.103 $\pm$ 0.014	3.21 $\pm$ 0.44	2.14 $\pm$ 0.20	4.28 $\pm$ 0.45	10.27 $\pm$ 1.36	6.97 $\pm$ 0.84	1.026 $\pm$ 0.00	ND	6.52 $\pm$ 0.10	0.07 $\pm$ 0.17	2.92 $\pm$ 1.03

TA = Titratable acidity (%lactic acid); TS = Total solids; SNF = Solids-not-fat; FPD = Freezing point depression; CC = Coliform count; TVC = Total viable count; Yield = Average daily milk yield per animal; ND = Not determined /// TA = Acidité titrable (% d'acide lactique); TS = Matière sèche totale; SNF = Extrait sec dégraissé; FPD = Abaissement du point de congélation; CC = Nombre de coliformes; TVC = Nombre total de bactéries viables; Yield = Rendement laitier quotidien moyen par animal; ND = Non déterminé

DISCUSSION

Milk yield

The milk yield of dromedary camels is influenced by several factors, including the production system and management practices (Aljumaah *et al.*, 2012; Babiker & El-Zubeir, 2014; Ayadi *et al.*, 2018),

Table VI: Effect of parity on the daily milk yield (mean $\pm$ SEM) of camels reared at Tsabong Ecotourism Camel Park during the wet season (mean yield of 20 animals) /// *Effet de la parité sur la production laitière quotidienne (moyenne $\pm$ SEM) des chamelles élevées au Tsabong Ecotourism Camel Park pendant la saison des pluies (production moyenne de 20 animaux)*

Parity	Milk yield (mL)
2	1150.09 $\pm$ 300.69
3	1332.64 $\pm$ 224.51
4	1362.77 $\pm$ 274.83
5	1666.43 $\pm$ 273.46
6	1240.84 $\pm$ 315.55

stage of lactation (Ahmad *et al.*, 2012; Al-Saiady *et al.*, 2012; Babiker & El-Zubeir, 2014; Abdalla *et al.*, 2015; Jemmali *et al.*, 2016; Nagy *et al.*, 2017; Hadeef *et al.*, 2018; Ashour *et al.*, 2019; Chamekh *et al.*, 2020; Koc *et al.*, 2025), parity (Ahmad *et al.*, 2012; Aljumaah *et al.*, 2012; Al-Saiady *et al.*, 2012; Babiker & El-Zubeir, 2014; Abdalla *et al.*, 2015; Nagy *et al.*, 2017; Ashour *et al.*, 2019), season of the year (Ahmad *et al.*, 2012; Abdalla *et al.*, 2015; Nagy *et al.*, 2017; Chamekh *et al.*, 2020), breed (Aljumaah *et al.*, 2012; Nagy *et al.*, 2017) and the nutrition/diet of the animals (Al-Saiady *et al.*, 2012).

In the present study, during the dry season (August to October) the average daily milk yield of camels (781 ml) was much lower than during the wet season (December to March), when it averaged 1,340 ml. Ahmad *et al.* (2012) reported that the mean daily milk yield of camels in Pakistan was significantly higher ($p < 0.01$) during the rainy season, followed by the winter season, the warm dry summer, and the hot summer season. On the other hand, Abdalla *et al.* (2015) reported that the milk yield of Maghrebi camels calving in winter (December to May) was 13.2% higher compared to camels calving in summer (June to November) in Egypt. Similarly, Chamekh *et al.* (2020) reported seasonal variations in camel milk yields, with the highest daily milk yield recorded during summer (June), and the lowest in winter (December) in Tunisia. Seasonal variations in camel milk yields can be attributed to availability and quality of feed, water supply, and seasonal variations in the animal's reproductive cycle (stage of lactation). In Botswana, winter (June to August) is the coldest and driest season, characterized by no rain and severe feed shortages. The dry season lasts until November when the rainy season (summer) starts. In Tsabong, the winter months coincide with the breeding (mating) season of the camels (Seifu *et al.*, 2019). The low milk yield observed during the dry season in the present study therefore could be attributed to the camels spending much of their time engaged in courtship behaviour, leaving them with little time for feeding. Seasonal variations in camel milk yields are associated with the stage of lactation, with peak milk yield occurring during the summer, while the decline in milk yield during late lactation coincides with harsh winter conditions (Musaad *et al.*, 2013; Chamekh *et al.*, 2020). The decline in milk yield in winter (the dry season) and the high milk yield in summer (the wet/rainy season) observed in the present study thus could partly be attributed to the corresponding changes in the stage of lactation of camels following the seasons. The low camel milk yield observed during the dry season in the present study suggests that there is a need to improve the feeding management of camels during the dry season and to formulate a ration that meets the nutrient requirements of the camels and increases milk production.

In the present study, the stage of lactation had different effects on the daily milk yield of camels during the dry and wet seasons. The stage of lactation significantly affected camel milk yield during the dry season but had no significant effect during the wet season. The daily milk yield of camels showed opposite trends during the dry and wet seasons. Milk yield decreased with advancing lactation during the dry season, whereas the opposite trend was observed during the wet season. Published literature reports show that stage of lactation is one of the major factors affecting milk yield in dromedary camels. A study conducted in Algeria showed that camel milk yield was significantly higher ($p < 0.05$) during mid lactation compared to early and late stages of lactation (Hadeef *et al.*, 2018). Another study of Maghrebi camels in Egypt (Abdalla *et al.*, 2015) revealed that the highest milk yield was recorded during mid lactation (≈ 3 months in lactation), while the lowest milk yield was recorded during late lactation. Al-Saiady *et al.* (2012) and Ayadi *et al.* (2018) also found that camels produced higher milk yields during mid lactation, and milk yield decreased towards the end of lactation. However, Jemmali *et al.* (2016) reported that milk yield of Maghrebi camels in Tunisia decreased with advancing lactation. Similarly, Ahmad *et al.* (2012)

reported that daily milk yield of camels was significantly higher in the first stage of lactation, while the lowest yield was recorded in the third stage of lactation. These reports correspond to the observations of the current study in the dry season, where daily milk yield decreased as the stage of lactation increased.

It is well established that the number of lactations (parity) exerts a significant effect on the milk yield of dairy animals such as cows. In dairy cows, milk yield generally increases with each successive parity up to a certain point, but then declines as parity increases further. Reports also indicate that the milk yield of dromedary camels is significantly influenced by the number of parturitions (Ahmad *et al.*, 2012; Aljumaah *et al.*, 2012; Babiker & El-Zubeir, 2014; Abdalla *et al.*, 2015; Nagy *et al.*, 2017). In the present study, camel parity exerted different effects on milk yield during the dry and wet seasons. In the dry season, a decrease in milk yield was observed with increasing parity, and the highest milk yield was observed for camels in their second parity. In contrast, milk yield increased with the number of parturitions up to the fifth parity, with the highest milk yield observed in camels at their fifth parity during the wet season. The decrease in milk yield observed with an increasing number of lactations in the dry season may be related to the loss of body condition in lactating camels at higher parities due to the feed shortages experienced at the study site during this season. Lee and Kim (2006) reported that dairy cows in higher parities may experience greater body condition loss during early lactation, which can negatively impact milk production. Given the small sample size (20 animals), the results of the present study should be interpreted with caution.

The higher fat content of camel milk observed in the wet season in the present study could be attributed to the camels' feed. During the wet season, there is abundant vegetation, whereas in the dry season, most of the vegetation that camels feed on, especially grasses and herbaceous plants, dries out and disappears. Feeds rich in good quality forage result in milk with a high fat content. High-quality, early harvested forage is highly digestible, which promotes better rumen fermentation, specifically stimulating the production of acetate and butyrate—the key precursors for fat synthesis in the udder (Infascelli *et al.*, 2025).

Babiker and El-Zubeir (2014) reported that dromedary camels in Sudan in their second parity produced the highest milk yield. This finding is consistent with the results observed in the present study during the dry season. An earlier report indicated that daily milk yield increased as the parity of camels advanced from the first to the fourth parity, and started declining significantly from the fifth parity (Ahmad *et al.*, 2012). This observation aligns with the findings of the present study in the wet season, where an increase in milk yield was observed with increasing number of parturitions up to the fifth parity. Ashour *et al.* (2019) found that the daily milk yield of Maghrebi camels in Egypt significantly increased at the third, fourth, and fifth parities compared to the first and second parities. Similarly, Abdalla *et al.* (2015) reported that parity significantly affected the milk yield of Maghrebi camels in Egypt, and the highest milk yield was recorded in camels at their sixth parity, which was significantly higher ($p < 0.05$) than the milk yield at their first parity. In the present study, camel milk production increased up to the fifth parity during the wet season; however, it then significantly decreased after that point. The highest milk yield was recorded for camels at their fifth parity during the wet season. This suggests that it is not economical to keep camels beyond their fifth parity, and hence such camels should be culled from the herd.

Composition and quality of milk

Variations in camel milk composition could be attributed to several factors including management systems (Bakheit *et al.*, 2008; Shuieip

et al., 2008; Aljumaah *et al.*, 2012; Riyadh *et al.*, 2012; Babiker & El-Zubeir, 2014; Ayadi *et al.*, 2018), season (Shuiep *et al.*, 2008; Ahmad *et al.*, 2012; Riyadh *et al.*, 2012; Ghude *et al.*, 2017; Nagy *et al.*, 2017; Chamekh *et al.*, 2020), stage of lactation (Ahmad *et al.*, 2012; Aljumaah *et al.*, 2012; Al-Saiady *et al.*, 2012; Riyadh *et al.*, 2012; Babiker & El-Zubeir, 2014; Abdalla *et al.*, 2015; Jemmali *et al.*, 2016; Nagy *et al.*, 2017; Hadeef *et al.*, 2018; Ayadi *et al.*, 2018; Ashour *et al.*, 2019; Chamekh *et al.*, 2020; Koc *et al.*, 2025), parity (Ahmad *et al.*, 2012; Aljumaah *et al.*, 2012; Babiker & El-Zubeir, 2014; Ghude *et al.*, 2017; Nagy *et al.*, 2017; Ashour *et al.*, 2019; Chamekh *et al.*, 2020), breed (Aljumaah *et al.*, 2012; Riyadh *et al.*, 2012; Nagy *et al.*, 2017), and feeding conditions (Bakheit *et al.*, 2008; Al-Saiady *et al.*, 2012).

Comparison of data from the dry and wet seasons in the present study shows that the season of the year has a strong effect on certain components of camel milk. The pH, fat, and TS contents of camel milk samples obtained during the wet season were generally higher than those obtained during the dry season. The high TS content observed in camel milk during the wet season could be attributed to the increased availability of high-quality, succulent forage and better-quality plants, leading to a higher concentration of nutrients in the milk compared to the dry season. Dry season milk often suffers from lower quality and reduced solids content due to nutritional stress (Nateghi *et al.*, 2014). The availability of abundant green feed and water prevents the dilution effect on milk that occurs during the dry season, resulting in a higher TS content (Nateghi *et al.*, 2014). The low TS content observed in camel milk during the dry season could also be attributed to the higher water content of camel milk in the dry season. Camels produce diluted milk in hot weather when water is scarce (Farah, 2011; Kanca, 2017) as a natural adaptation to provide not only nutrients but also essential fluids to dehydrated calves (Yagil & Etzion, 1980). According to Yagil and Etzion (1980), the fat percentage, TS content, protein, and lactose levels in camel milk decrease when the animals are dehydrated.

Similarly, the total CC in camel milk samples obtained during the wet season were higher than milk samples obtained during the dry season. Ghude *et al.* (2017) reported significantly ($p < 0.05$) higher TS, SNF, fat, and ash contents of camel milk during the hot-dry season compared to the wet season. Their observations for fat and TS contents are consistent with the findings of the present study. On the other hand, Shuiep *et al.* (2008) indicated that camel milk samples collected in the summer in Sudan showed significantly higher protein content and titratable acidity in samples collected from semi-intensive system, whereas in winter, all milk components were higher than those examined in summer in both production systems studied (semi-intensive system and traditional system). Ahmad *et al.* (2012) reported higher fat and protein contents for camel milk obtained during the hot, dry summer, while lactose content was higher during the rainy season. Mean fat, protein, SNF, and TS concentrations showed a high seasonal variation (9.5 to 28.7%), with the lowest and highest values measured during summer and winter, respectively (Nagy *et al.*, 2017).

In the present study, the stage of lactation had a significant effect on the composition of camel milk, especially during the dry season. The protein, SNF, and density of the camel milk samples were significantly higher at early lactation, while the highest fat content was recorded for milk samples collected during mid lactation. Protein and SNF contents decreased with advancing lactation during the dry season. Only the protein content showed a significant difference during the wet season, which was high at early lactation. Babiker and El-Zubeir (2014) reported that camel milk has the highest fat, protein, lactose, and SNF contents during the early stage of lactation. Ahmad *et al.* (2012) also reported that the protein and lactose contents of camel milk were significantly lower ($p < 0.01$) at the third stage of lactation but higher in the first and second stages of lactation. However, the SNF content was significantly higher ($p < 0.01$) in the

first stage of lactation. Hadeef *et al.* (2018) found the highest density, fat, and TS contents in camel milk during the first stage of lactation. Similarly, Aljumaah *et al.* (2012) and Ashour *et al.* (2019) indicated that the highest mean fat, protein, lactose, and SNF contents were recorded for camels in their first stage of lactation.

Parity was one of the factors that influenced the composition of camel milk during both the dry and wet seasons in the present study. During the dry season, the highest TA and protein content were found in milk samples from camels at their second parity, whereas the lowest TA and protein content were found in milk samples from camels at their third parity. In contrast, the lactose content of the milk was highest in parity three and lowest in parity two. The lactose content of the camel milk showed an opposite trend to the protein content. In the wet season, parity had significant ($p < 0.05$) effect on the protein, lactose, TS, SNF, and pH of camel milk samples. The highest protein, lactose, TS and SNF contents were observed in milk samples from camels at their second parity, while the lowest pH, lactose, and SNF contents were observed in milk samples from camels at their fourth parity.

Babiker and El-Zubeir (2014) reported that the highest protein, lactose, and SNF contents were recorded in the milk of camels at their fifth parity. The lactose content of camel milk was reported to be significantly affected by parity, and showed an increasing trend from the first to fifth parity, followed by a decline at the sixth parity (Ahmad *et al.*, 2012). Ashour *et al.* (2019) reported that protein, lactose, and TS contents of milk of Maghrebi camels were significantly ($p < 0.05$) lower in the fifth parity than other parities. Another study showed that parity had a significant effect on milk composition, with all chemical components being higher in milk from primiparous camels than from multiparous camels (Chamekh *et al.*, 2020).

No significant differences ($p > 0.05$) were observed in TVC and CC in camel milk between different stages of lactation and different parities in both the dry and wet seasons. However, the CC of camel milk was generally higher during the wet season than in the dry season. The increase in CC in the wet season could be attributed to the moist environment resulting from the heavy rainfall during this season, which provides favourable conditions for the growth and proliferation of coliforms. It could also be related to the poor hygienic practices of the milkers, exacerbated by the high precipitation that increases the chance of microbial contamination in the milk.

Although the prevalence was low, *Salmonella* species were detected in camel milk samples collected during both the dry season (3.42%) and the wet season (1.7%). *Salmonella* species are pathogenic bacteria, and from a safety point of view, not even a single cell of a pathogen should be present in the milk samples. The detection of *Salmonella* species in the raw camel milk samples examined in the present study suggests a serious public health risk, and thus calls for a mandatory pasteurization of camel milk before consumption to ensure its safety. The results of the microbial analysis suggest a need to follow strict hygienic and sanitation measures during the milking of camels and the handling of the milk, as well as a need for heat treatment of the milk to improve the quality and safety of camel milk produced at the Tsabong Ecotourism Camel Park.

CONCLUSION

Based on the study at Tsabong Ecotourism Camel Park, camel milk yield and quality are strongly influenced by season, parity, and lactation stage, with significantly lower production during the dry season and after the fifth parity. To enhance productivity, it is recommended to implement supplementary feeding (e.g., *Cenchrus ciliaris* and *Atriplex nummularia*), conduct genetic selection, and manage herd age by culling camels after their fifth parity. Finally, due to the high

levels of coliforms and the presence of *Salmonella* in raw milk, strict hygiene measures and mandatory pasteurization are essential to mitigate public health risks and ensure food safety. Overall, the findings suggest that using camels for dairy production to improve local food security and provide economic opportunities could be a viable way to diversify their role in Botswana's economy.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

ES conceptualized the study; led the project; designed the methodology; conducted the experiment; prepared the draft manuscript; edited and reviewed the manuscript; ORM co-led the project; conducted formal analysis; contributed to the reviewing and editing; WSB, MM investigated the data; AA, DT co-led the project; contributed to the reviewing and editing; KM designed the methodology and investigated the data; RKL, GDH, GB, KK, BSM, WM contributed to the reviewing and editing; OMM, BRB, BM, NT collected data.

Ethics approval

This research was approved by the Research, Technology Development and Transfer Committee (RTDTC) of the Botswana University of Agriculture and Natural Resources.

Access to research data

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declaration of Generative AI in the writing process

The authors declare they have not used Artificial Intelligence tools in the creation of this article.

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Résumé

Seifu E., Madibela O.R., Boitumelo W.S., Angassa A., Mpho K., Molapisi M., Kobue-Lekalake R., Haki G.D., Bultosa G., Teketay D., Moeng O.M., Bogatsu B.R., Mokobi B., Tselaesele N., Kgosikoma K., Sekwati-Monang B., Mojeremane W. Effets de la saison, de la parité et du stade de lactation sur le rendement, la composition et la qualité microbienne du lait de chamelles élevées à Tsabong, au Botswana

Contexte : Introduits au Botswana au début du XX^e siècle, les dromadaires restent peu exploités pour la production laitière. À Tsabong, le troupeau est principalement dédié au tourisme et aucune étude n'a encore évalué les facteurs influençant le rendement ni la composition du lait de chamelle. **Objectif :** Cette étude a été menée afin d'évaluer les effets de la saison, de la parité et du stade de lactation sur le rendement, la composition et la qualité du lait de chamelle. **Méthodes :** Vingt chameaux en lactation, âgés en moyenne de huit ans et se trouvant à différents stades de lactation (début, milieu et fin) et ayant eu entre deux et six portées, ont été étudiés. Ils broutaient librement pendant la journée et recevaient 3 kg d'un complément alimentaire composé à parts égales de saltbush et de son de sorgho la nuit, avec un accès illimité à l'eau et au sel. La production laitière a été mesurée tous les trois jours pendant six semaines. Au total, 560 enregistrements ont été recueillis pendant la saison sèche et 640 pendant la saison humide. Des échantillons de lait destinés à des analyses chimiques et microbiologiques ont été prélevés six fois sur une période de deux semaines. **Résultats :** Les rendements laitiers étaient nettement plus élevés pendant la saison des pluies (1 340 ml/jour) que pendant la saison sèche (781 ml/jour). En saison sèche, le rendement laitier diminuait à mesure que le nombre de vêlages augmentait, tandis qu'en saison des pluies, il augmentait jusqu'au cinquième vêlage avant de baisser. Le stade de lactation a eu une influence significative sur la teneur en matière grasse, en protéines, en matière sèche non grasse et sur la densité en saison sèche. Le lait en début de lactation présentait des teneurs plus élevées en protéines, en extrait sec dégraissé et en densité, tandis que la teneur en matière grasse atteignait son maximum en milieu de lactation. Pendant la saison humide, seule la teneur en protéines variait de manière significative selon les stades de lactation. La parité a eu une incidence significative sur l'acidité titrable, les protéines et le lactose pendant la saison sèche, ainsi que sur les protéines, le lactose, les solides totaux, l'extrait sec dégraissé et le pH pendant la saison humide. Les valeurs les plus élevées ont été observées chez les chamelles à leur deuxième parité pendant la saison humide. La teneur en matières grasses et en matières sèches totales était globalement plus élevée pendant la saison humide. Les nombres de coliformes étaient généralement plus élevés dans les échantillons prélevés pendant la saison humide. Des salmonelles ont été détectées dans 3,42 % des échantillons de la saison sèche et dans 1,7 % des échantillons de la saison humide. **Conclusions :** Ces résultats soulignent la nécessité d'améliorer les conditions d'hygiène lors de la traite et l'importance d'un traitement thermique avant la consommation.

Mots-clés: dromadaire, rendement laitier, composition du lait, contamination microbienne, stade de lactation, variation saisonnière, Botswana

Resumen

Seifu E., Madibela O.R., Boitumelo W.S., Angassa A., Mpho K., Molapisi M., Kobue-Lekalake R., Haki G.D., Bultosa G., Teketay D., Moeng O.M., Bogatsu B.R., Mokobi B., Tselaesele N., Kgosikoma K., Sekwati-Monang B., Mojeremane W. Efectos de la estación, el número de partos y la fase de lactancia sobre el rendimiento, la composición y la calidad microbiana de la leche de camellas criadas en Tsabong, Botsuana.

Contexto: Los dromedarios, introducidos en Botsuana a principios del siglo XX, continuaban poco explotados para la producción lechera. En Tsabong, el rebaño se destina principalmente al turismo, y ningún estudio ha evaluado todavía los factores que influyen en el rendimiento ni la composición de la leche de camella. **Objetivo:** Este trabajo se ha llevado a cabo para evaluar los efectos de la temporada, del número de partos y del estadio de lactancia en el rendimiento, la composición y la calidad de la leche de camella. **Métodos:** Se estudiaron 20 camellas en lactancia, con edades medias de ocho años; que se encontraban en diferentes estadios de lactancia (principio, medio y fin), y que habían tenido entre dos y seis camadas. Pacían libremente durante la jornada y por la noche recibían 3 kg de un complemento alimentario compuesto en partes iguales de *saltbush* y salvado de sorgo, con un acceso ilimitado al agua y a la sal. La producción lechera se midió cada tres días durante seis semanas. En total, se recogieron 560 registros durante la temporada seca y 640 durante la estación húmeda. Se tomaron muestras de leche destinadas a análisis químicos y microbiológicos seis veces durante un período de dos semanas. **Resultados:** Los rendimientos lecheros fueron claramente más elevados durante la estación lluviosa (1 340 ml/día) que durante la estación seca (781 ml/día). En la estación seca el rendimiento lechero disminuía a medida que el número de partos aumentaba, mientras que, en la estación lluviosa, aumentaba hasta el quinto parto y luego disminuía. El estadio de lactancia tenía una influencia significativa en el contenido en materia grasa, proteínas y materia no grasa, y en la densidad, en la estación seca. La leche al principio de la lactancia presentaba contenidos más elevados en proteínas y en extracto seco desgrasado, y mayor densidad, mientras que el contenido en materia grasa alcanzaba su máximo en medio de la lactancia. Durante la estación húmeda, solo el contenido en proteínas variaba de manera significativa según los estadios de lactancia. El número de partos tuvo una incidencia importante en la acidez titulable, las proteínas y la lactosa durante la estación seca; mientras que tuvo mayor incidencia sobre las proteínas, la lactosa, los sólidos totales, el extracto seco desgrasado y el pH durante la estación húmeda. Los valores más elevados se observaron en las camellas en su segundo parto durante la estación húmeda. El contenido en materia grasa y materia seca total fue globalmente más elevado durante la estación húmeda. El número de coliformes fue generalmente más elevado en las muestras tomadas durante la estación húmeda. Se detectaron salmonelas en el 3,2 % de las muestras de la estación seca y en el 1,7 % de las muestras de la estación húmeda. **Conclusiones:** Estos resultados destacan la necesidad de mejorar las condiciones de higiene durante el ordeño y la importancia de un tratamiento térmico antes del consumo.

Palabras clave: dromedario, rendimiento lechero, composición de la leche, contaminación microbiana, etapa de la lactancia, variación estacional, Botswana