The influence of weather conditions on body temperature, milk composition and yields of the free-ranging dromedary camels in Southeastern rangelands of Ethiopia

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Abstract: This study aimed to investigate the effect of heat stress and seasons on diurnal body temperature, milk yield, and physicochemical properties of dromedary camel in southeastern rangelands Ethiopia. Twenty lactating camels with 2–3 months postmortem and 3–4 parities were selected for evaluation of milk yield, physicochemical properties, and body temperature measurements. The current finding shows diurnal body temperature was significantly higher in hot weather conditions (dry season). Temperature-humidity index (THI=\text{max}) showed a strong positive correlation to rectal body temperatures (r = 0.72) and daily milk yield (r = 0.6) of a camel. The mean daily milk yield observed in this study was 6.02, 4.99, 2.38, and 2.57 Liters (L) during autumn, spring, summer, and winter, respectively, and showed higher (P < 0.001) milk yield in rainy season. Mean percentage of protein (3.1%), casein (1.9%), lactose (4.9%), solid-not-fat (SNF) (8.53%), and total solids (TS) (12.7%) was greater (P < 0.001) in wet season. Milk fat and energy-
corrected milk (ECM) concentrations did not vary (p > 0.05) across the seasons. The body temperature, milk physicochemical properties, and yield of dromedary camels were varied (p < 0.001) with local weather conditions and seasons. However, further investigation based on animal trials at on-station is needed in order to confirm the on-farm camel milk yield and physicochemical quality observed in this study.

**Subjects:** Agriculture; Agriculture and Food; Nutrition Substitutes;

**Keywords:** Camel; Chemical properties; Heat stress; Milk; Temperature-humidity indexAgriculture; Agriculture and Food; Nutrition; Substitutes – Food Chemistry; Dairy Science

1. Introduction
Camel and goat are the preferred livestock species in arid, semi-arid, and drought-prone regions (Abroulaye et al., 2015; Faraz et al., 2019a, 2019b, 2019c). The microclimatic condition, mainly temperature and humidity, directly impacts animal physiology and responds to heat stress by the dissipation of surplus body heat to the environment. When the ambient temperature and relative humidity increase, maintaining stable body temperature through heat dissipation mechanism may become effective, and the animal may enter into a state of heat stress (Ouellet et al., 2019). The animal responds to heat stress through several physiological processes such as decreasing dry matter intake, milk yield, and reproduction, and thus, will have a considerable influence on the overall production and reproduction performance (Schüller et al., 2014; Wheelock et al., 2010). Accordingly, the elevated body temperature affects milk yield and its chemical composition (Pragna et al., 2017). According to Rhoads et al. (2009), heat stress leads to physiological change (65%) and decreasing dry matter intake (35%) which reduces milk yield by 65 and 35%, respectively.

Several studies indicated a decline in milk yield and fat contents under high ambient environmental temperature (Bernabucci et al., 2014; Nagy et al., 2017; Ouellet et al., 2019). Under the climate change scenario, the evaluation of environmental interaction with livestock and the knowledge of heat stress is profoundly increasing interest (Hamamami et al., 2013). According to Liang et al. (2013), reticulorumen temperature of dairying cattle found to be influenced by ambient temperature and milk production. The camel's core body temperature was maintained nearly at 36.5°C with the range of 36°C to 37°C and consistently varies with ambient temperature with of low amplitude (Al-faraj & Al-haidary, 2001). However, Schmidt-nielsen et al. (1956) revealed that body temperature of the camel fluctuates from 34°C to 40°C within a wide range of environmental condition. Temperature-humidity index calculated from ambient temperature and relative humidity was the best heat stress measure in dairying animal. Dairying animal subjected to heat stress shows a significant change in milk yield and chemical composition. Moreover, Du Preez et al. (1990) found that milk yield from dairying cattle was declined during the dry season compared with a wet period. The amount of milk yield drops by 0.41 kg/cow/day with increasing temperature-humidity index value above 69 (Bourraoui et al., 2002). Heat stress also significantly influence milk chemical composition (Du Preez et al., 1990).

Most studies focused on the impacts of heat stress on cattle; however, its implications for dairying camel were limited. The chemical composition of camel’s milk varies substantially based on geographical location, types of feed, and the camel breeds (Faraz et al., 2020; Al Haj & Al Kanhal, 2010). Camels are known for their sustaining milk yield (lactating for a prolonged period) even under drought condition and heat stress (Faraz, 2020). A camel can produce a larger milk volume than other milk-producing farm animals, more than four times milk per day than that of cattle and much more than goat under similar lactation and environmental condition. Nonetheless, under heat stress, dairying animal was found to reduce milk yield and chemical composition (Al-jassim & Sejian, 2015; Faraz et al., 2021; Sisay & Awoke, 2015; Yohannes et al.,
Although some studies particularly on camel milk composition under heat stress were conducted in some countries in the world, there are few on the evaluation of effects of heat stress on dairying camel in Africa, including Ethiopia that focused on microclimatic and seasonal variations. Dereje et al. (2016) have tried to address the impacts of concentrate supplementation on free-ranging dromedary camel on milk yield and physicochemical composition regardless of location effect and the vegetation types for camel feed in the range and seasonal variation. Yet, the impacts of heat stress and seasonal variations on camel body temperatures, milk yield, and chemical composition were not addressed so far in Ethiopia. Therefore, it is beneficial to generate information on effects of heat stress and seasonal variations on camel milk yield, composition and body temperature. Thus, this study aimed to investigate the effect of heat stress and seasons on diurnal body temperature, milk yield, and physicochemical properties of free-ranging camels rearing in southeastern rangelands of Ethiopia. It was hypothesized that seasons, ambient temperature, and relative humidity can influence diurnal body temperature, milk yield, and physicochemical properties of the dromedary camels.

2. Material and methods

2.1. Study location

The study was conducted in the semi-arid area of East Guji Zone southeast Ethiopia. It is located between 40° 38’ 55” and 50° 33’ 7” N latitude, and 39° 9’ 25” and 39° 58’ 37” E longitude, and covers about 742,644 ha. The locations are categorized as a pastoral and agro-pastoral region that belongs to the semi-arid lowland agro-ecological zone. The altitude of the study districts ranges between 1370 and 1650 m a.s.l. The annual temperature of the area varies from 24 to 30 °C with a mean annual rainfall of 527 mm. The pattern of the rain is bimodal with the main rainy season (Ganna) contributing about 60% of yearly rainfall, which extends from March to May while dry season ranges from December to February (Adi & Swoboda-reinhold, 2003).

2.2. Sampling and data collection

The study was conducted under semi-arid climatic conditions classified as lowland geographical regions in Ethiopia’s southeastern rangelands. Three study districts and six kebeles (the smallest administrative unit of the Ethiopian Government) were randomly selected from the five pastoral and agro-pastoral districts of East Guji Zone based on the drawing lots procedure indicated in Gomez & Gomez (1984). Camel owners were purposively selected based on the ownership of lactating dromedary camels within the range of 2–3 months postmortem and 3–4 parities at this study’s commencement time.

The data set used in the current study was collected from free-ranging 20 dairying dromedary camels for milk yield monitoring and body temperature evaluations to examine climate variability. Twenty lactating dromedaries with 2–3 months postmortem and 3–4 parities were selected since camels with 3–4 parities and lactating up to one year were found to be similar in milk yield and chemical properties (Ahmad et al., 2012; Idrees et al., 2016; Mostafa et al., 2018; Raghvendar et al., 2004; Riek & Gerken, 2006). Daily milk yield was recorded weekly, and milk chemical composition and body temperatures were measured both at dry and wet seasons. Camels were milked three times daily at 06:00AM—07:00AM, 12:00PM—01:00PM, and 06:00PM—7:00PM. The analysis of milk chemical composition was compiled from milk samples collected in the last week of January (dry and hot season) and the second week of May (wet and cold period) using MilkoScan (MilkoScan™ FT2, Foss, all liquid dairy products analyzer) at dairy laboratories. The pH value of fresh milk was taken immediately after milking in the field using Extech waterproof pH meter (pH90, temperature-0 to 90°C, resolution: pH0.01, power: Two 3 V CR3032 button batteries). The collected milk samples were treated with 0.4% of Potassium dichromate (K2Cr2O7) immediately after milking since herd milk samples preserved with K2Cr2O7 in concentrations of 0.3–0.4% maintain milk compositions for 20 days under refrigeration and suitable for infrared milk tester (Barbano et al., 2010; Upadhyay et al., 2014). The collected samples were transported to laboratory stations using an icebox on the same day after milking.
The initial dataset related to rectal and infrared body temperature was collected hourly during the third weeks of January (dry and hot period) and the first week of May (wet and cold period). Rectal temperature dataset was recorded using environmental-friendly and safe digital thermometer (Gen-X digital thermometer, VM-101, 32–42 °C). Whereas infrared body temperature was collected from no-contact forehead digital infrared thermometer (Digital infrared thermometer, HT-826, −50 + 550°C). The environmental humidity and temperature dataset corresponding to body temperature measurement were collected from hygro-thermometer (Digital Thermo-hygro, 13,309, −50 + 70 °C/20-109 % RH, Jumbo).

2.3. Determination of energy-corrected milk (ECM)

The amount of energy contained in the milk was determined from protein yields, fat, and lactose using energy-corrected milk adjusted to 3.14 MJ/kg and included into the dataset (Madsen et al., 2008).

\[
\text{ECM (kg/d)} = 23.8 \times (\text{Protein yield}) + 38.9 \times (\text{Fat yield}) + \frac{16.3 \times (\text{lactose yield})}{3.14}
\]

where: ECM (Kg/d) = Energy-corrected milk in Kilogram per day;

2.4. Temperature and humidity data

Hourly reading of maximum temperature and minimum relative humidity was retrieved from seven days of the wet and dry seasons. Hourly readings have been then expressed per calendar day using maximum temperature (°C) and corresponding minimum relative humidity value. Daily maximum temperature (°C) and minimum relative humidity have been averaged on a seasonal basis to represent weather conditions prevailing in the current study as per the procedure followed by Ouellet et al. (2019).

2.5. Heat stress determination

The collected weather data were used to determine maximum temperature-humidity index (THI\text{max}) using index equation reported by Kendall et al. (2008):

\[
\text{THI}_{\text{max}} = (1.8 \times \text{Tmax} + 32) - ((0.55 - 0.0055 \times \text{RHmin}) \times (1.8 \times \text{Tmax} - 26))
\]

where: THI\text{max} is the daily maximum temperature-humidity index; RHmin is daily minimum relative humidity; T\text{max} is daily maximum Temperature (°C). The daily maximum THI equation was chosen because it was previously used in animal trial at all the representative climatic condition (Dikmen & Hansen, 2009; Schüller et al., 2014; Shock et al., 2016) and it has best-fit public weather station data (Ravagnolo & Misztal, 2002). The weather data obtained from the national meteorological agency collected from Negelle station was assumed to represent the overall on-farm environmental condition. According to Du Preez et al. (1990), the heat stress threshold for dairying animal was 71 THI value and animal experiencing heat stress at 72 THI, where the stress rate was classified into mild stress (72–79 THI), moderate stress (80–89 THI), and severe (90 and above THI).

2.6. Statistical analysis

All data measured on milk yield and chemical composition from individual camels were analyzed using SAS and R-softwares. Seasonal variation of the milk yield and chemical composition were determined by one-way analysis of variance methods using the general linear model (GLM) procedure of SAS (2010) for windows. Mean separation was employed using Duncan multiple range tests (Duncan, 1955). The correlation coefficient of THI\text{max} and measured body temperature were computed by using “ggpubr” package of R-Software (Kassambara, 2018). Moreover, Pearson product-moment correlation was used to measure the association between weather condition versus camel physiological response (Chee, 2013).
| Parameters     | Dry and Hot          | Wet and Cold         |
|---------------|----------------------|----------------------|
|               | Mean ± Std. Dev      | Min      | Max      | Mean ± Std. Dev      | Min      | Max      |
| BT (°C)       |                      |          |          |                      |          |          |
| Infrared      | 33.6 ± 3.76a         | 26.2     | 38.1     | 31.8 ± 3.09b         | 26.0     | 38.10    |
| Rectal        | 36.4 ± 1.41a         | 34.1     | 40.4     | 35.3 ± 0.91b         | 33.9     | 39.20    |
| Tmax (°C)     | 25.3 ± 3.06a         | 18.0     | 31.3     | 22.3 ± 2.54b         | 15.0     | 27.40    |
| RHmin         | 49.7 ± 8.97b         | 34.0     | 74.3     | 80.3 ± 11.6c         | 53.7     | 107.0    |
| THI_max       | 71.9 ± 3.52a         | 62.9     | 78.6     | 70.3 ± 3.52c         | 58.9     | 77.5     |

*Means in the same row with different superscript letter are different at P < 0.05*
3. Result and Discussion

3.1. Heat stress and body temperature

Mean daily THImax were about 72 with 63 minimum and 79 maximum during dry season. About 70 THImax with 59 minimum and 77.5 maximum were recorded in wet season (Table 1), indicating that camels were experiencing heat stress during dry season. The THImax value recorded in this study was higher ($p < 0.001$) in dry season depicting that dromedary camels experience heat stress during dry season since THImax values with greater or equal to 72 were classified as heat stress threshold (Du Preez et al., 1990). However, the recent finding by Jordan (2003) in Arizona revealed that dairy animals experience heat stress when THImax value exceeds 68. THImax value showed that dairying camels in the studied area was influenced ($p < 0.001$) by heat stress during dry and wet seasons. In agreement with the current finding, Ouellet et al. (2019) revealed higher THImax value during summer (dry and hot) season as compared with winter period (wet and cold).
The mean daily maximum temperature (Tmax) was higher \((p < 0.001)\) while the minimum relative humidity (RHmin) found to be lower \((p < 0.001)\) during dry and hot season as compared to the wet and cold period. Similarly, Ouellet et al. (2019) reported that minimum relative humidity was lower in wet and cold seasons, whereas the maximum ambient temperature was higher during dry season comparing with the wet season. The core body temperature of dairying cow varies with seasons and the recorded body temperature during summer season was highly significant than winter, indicating the effect of season and microclimatic conditions on body temperature of an animal (Liang et al., 2013). According to Collier et al. (1982), weather conditions such as relative humidity, ambient temperature, and solar radiation directly or indirectly influence the animal physiology.
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### Table 2. Milk yield observed during monitoring in liter (Mean ± Std)

| Season  | Months          | Morning            | Daytime            | Evening            | Mean daily |
|---------|-----------------|--------------------|--------------------|--------------------|------------|
| Autumn  | March           | 2.50 ± 0.67<sup>a</sup> | 1.88 ± 0.70<sup>b</sup> | 1.41 ± 0.62<sup>b</sup> | 5.79 ± 1.80<sup>b</sup> |
|         | April           | 2.53 ± 0.80<sup>b</sup> | 1.65 ± 0.63<sup>c</sup> | 1.31 ± 0.60<sup>c</sup> | 5.49 ± 1.66<sup>b</sup> |
|         | May             | 2.55 ± 0.73<sup>b</sup> | 1.86 ± 0.64<sup>c</sup> | 1.43 ± 0.62<sup>c</sup> | 5.83 ± 1.90<sup>a</sup> |
|         | June            | 2.97 ± 0.62<sup>a</sup> | 2.27 ± 0.66<sup>c</sup> | 1.73 ± 0.56<sup>a</sup> | 6.97 ± 1.62<sup>b</sup> |
|         | Mean            | 2.64 ± 0.73        | 1.92 ± 0.69        | 1.47 ± 0.62        | 6.02 ± 1.83  |
| Spring  | September       | 2.26 ± 0.61<sup>c</sup> | 1.71 ± 0.61<sup>bc</sup> | 1.24 ± 0.53<sup>c</sup> | 5.21 ± 1.59<sup>c</sup> |
|         | October         | 2.38 ± 0.73<sup>bc</sup> | 1.77 ± 0.62<sup>bc</sup> | 1.34 ± 0.54<sup>bc</sup> | 5.49 ± 1.75<sup>bc</sup> |
|         | November        | 1.90 ± 0.54<sup>a</sup> | 1.36 ± 0.45<sup>cd</sup> | 0.95 ± 0.44<sup>cd</sup> | 4.21 ± 1.31<sup>d</sup> |
|         | Mean            | 2.19 ± 0.66        | 1.62 ± 0.59        | 1.18 ± 0.53        | 4.99 ± 1.66  |
| Summer  | July            | 1.71 ± 0.41<sup>d</sup> | 1.19 ± 0.39<sup>ef</sup> | 0.79 ± 0.33<sup>ef</sup> | 3.69 ± 1.01<sup>ef</sup> |
|         | August          | 1.99 ± 0.60<sup>a</sup> | 1.36 ± 0.57<sup>cd</sup> | 0.95 ± 0.51<sup>cd</sup> | 4.30 ± 1.57<sup>d</sup> |
|         | Mean            | 1.86 ± 0.54        | 1.29 ± 0.50        | 0.88 ± 0.44        | 4.02 ± 1.38  |
| Winter  | December        | 1.29 ± 0.22<sup>cd</sup> | 0.78 ± 0.18<sup>fg</sup> | 0.31 ± 0.26<sup>fg</sup> | 2.38 ± 0.40<sup>g</sup> |
|         | January         | 1.48 ± 0.22<sup>de</sup> | 0.94 ± 0.22<sup>fg</sup> | 0.58 ± 0.21<sup>fg</sup> | 3.01 ± 0.53<sup>fg</sup> |
|         | February        | 1.17 ± 0.28<sup>fg</sup> | 0.73 ± 0.23<sup>fg</sup> | 0.36 ± 0.22<sup>fg</sup> | 2.26 ± 0.57<sup>fg</sup> |
|         | Mean            | 1.32 ± 0.27        | 0.82 ± 0.23        | 0.42 ± 0.26        | 2.57 ± 0.61  |

<sup>abcd/ef</sup> Means in the same row with different superscript letter are different at P < 0.05

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The body temperature (BT) of the camel that was expressed in terms of rectal and infrared was significantly higher (p < 0.001) during dry and hot period than wet and cold seasons. The measured rectal temperatures ranged from 34.1 to 40.4°C with a mean temperature of 36.4°C in dry season while infrared forehead measurement lies between 26.2 and 38.1°C with an average temperature of 33.8°C during dry and hot season. This finding showed lower (p < 0.001) rectal (35.3°C) and forehead infrared (31.8°C) body temperature of the camel during wet and cold seasons (Table 1). The current finding agreed with Al-faraj and Al-haidary (2001) who reported the mean diurnal...
Table 3. Milk Chemical composition (Mean ± STD)

| Season | Dry  | Wet  |
|--------|------|------|
|        | Mean ± STD | Min  | Max  | Mean ± STD | Min  | Max  |
| Fat    | 3.87 ± 1.42 | 2.06 | 9.23 | 3.72 ± 1.89 | 1.00 | 8.63 |
| Protein | 2.46 ± 0.47b | 1.29 | 3.36 | 3.19 ± 0.80b | 1.74 | 5.22 |
| Casein  | 1.70 ± 0.32b | 0.95 | 2.34 | 1.90 ± 0.39b | 1.12 | 2.93 |
| TS     | 11.6 ± 2.13b | 7.28 | 17.8 | 12.7 ± 2.43b | 8.45 | 17.6 |
| SNF    | 7.26 ± 1.20b | 4.21 | 9.14 | 8.53 ± 1.61b | 5.59 | 11.7 |
| Lactose | 4.41 ± 0.70b | 2.67 | 5.36 | 4.90 ± 0.77b | 3.34 | 5.99 |
| TD     | 13.6 ± 3.79b | 5.56 | 22.7 | 11.9 ± 1.71b | 6.86 | 14.2 |
| TD     | 15.5 ± 4.23b | 7.13 | 25.9 | 13.5 ± 1.72b | 8.80 | 16.0 |
| Lactic Acid | 0.14 ± 0.04b | 0.06 | 0.23 | 0.12 ± 0.02b | 0.07 | 0.14 |
| Density | 1030.5 ± 4.58 | 1023.1 | 1039.5 | 1029.4 ± 4.71 | 1022 | 1039 |
| Citric acid | 0.13 ± 0.03b | 0.07 | 0.19 | 0.11 ± 0.03b | 0.05 | 0.16 |
| FFA    | -0.15 ± 0.26 | -1.09 | 0.20 | -0.11 ± 0.23 | -0.78 | 0.27 |
| pH (fresh) | 6.40 ± 1.00b | 5.10 | 8.70 | 7.03 ± 1.48b | 4.10 | 8.90 |
| ECM    | 2.32 ± 0.60 | 1.55 | 4.47 | 2.46 ± 0.79 | 1.47 | 4.78 |

where SNF = Solid not fat; TS = Total solid; TD = Dornic acidity; DT = Thermer acidity; FFA = Free fatty acids; ECM = Energy-corrected milk. ab Means in the same row with different superscript letter are different at P < 0.05

rectal temperature of 36.5°C. Similarly, Schmidt-nielsen et al. (1956) disclosed that the diurnal rectal temperature of dromedary varies with season and ranges from 34 to above 40°C. According to Renaudeau et al. (2012), the animal body temperature changes reflect thermal equilibrium to local weather condition. The current study showed that wide variation between daily maximum and minimum body temperature of dairying camel, indicating a significant difference of diurnal body temperature (Table 1). Likewise, Ipema et al. (2008) reported significant variation between dairy cow’s minimum and maximum body temperature.

The mean diurnal rectal temperature measured during dry season ranging from 35.4 to 37.9°C while 34.7 to 36.1°C were recorded in wet season. In contrast, mean diurnal temperature observed from infrared forehead thermometer was varied from 29.2 to 37.3°C in dry season and 27.9 to 35.8°C during wet season (Figure 1). The highest body temperature was recorded during the late afternoon from 8:00 PM to 10:00 PM. The lowest body temperature was observed during the early morning from 5:00 AM to 6:00 AM at both seasons. In agreement with the current finding, Bitman et al. (1984) observed the lowest body temperature during the early morning. Similarly, Lefcourt and Adams (1998) reported higher body temperature during the afternoon, and the lowest value was recorded in the early morning. According to Abdoun et al. (2012) and Al-faraj and Al-haidary (2001), the minimum value of the camel body temperature was documented in the early morning at 06:00 hours, and the maximum value was observed during the afternoon between 12:00 and 15:00 hours.

Figure 2 shows the thermophysiological response of the studied camels to environmental conditions in the studied area. The result of the current study revealed significantly (p < 0.001) positive relationship between camel body temperature and temperature-humidity index values, indicating the increasing camel body temperature with increasing value of the temperature-humidity index. Strong positive correlation was observed between temperature-humidity index and rectal temperature with |r| = 0.72 (p < 0.001) and the association between infrared temperature versus temperature-humidity index showed moderate correlation with |r| = 0.49 (p < 0.001) since correlation coefficient of 0.3 < |r| < 0.5 is defined as moderate correlation and |r| > .5 values indicating strong correlation between the two variables (Chee, 2013). In agreement with the current finding, Abdoun et al. (2012) reported moderately a positive correlation of temperature-
humidity index value versus body surface and camel’s skin temperature. According to Al-haidary et al. (2013), higher (p < 0.001) rectal and surface body temperature of the camel was recorded corresponding with temperature-humidity index in summer compared to spring season. Moreover, Liang et al. (2013) revealed consistently positive relationship between ambient temperature and core body temperature of dairying animals and reported greater environmental conditions on animal body temperatures.

3.2. Milk yield
Meteorologically, there are four hydrological seasons in east Guji zone; autumn (wet and cold period), summer (dry and cold period), spring (wet and hot period), and winter (dry and hot period). Autumn (March—June) is the long rainy season while spring (September—November) is short and erratic rainfall period. Winter (December—February) is the driest season of the year and spring (June—August) is moderately dried period between the long rainy season (autumn) and the short rainy season (spring) in east Guji zone (Abate, 2016; Alhamshry et al., 2019; NMA, 2015).

The mean morning milk yield during autumn (2.64 l), spring (2.19 l), summer (2.19 l) and winter (1.32 l) were higher than mid-day and evening milking time. The mean daily milk yields during autumn, spring, summer, and winter were 6.02, 4.99, 4.02, and 2.57 l, respectively (Table 2). Camel milk yield during autumn (long rainy season) was greater (p < 0.001) than spring, summer, and winter seasons. Spring daily milk yield was higher (p < 0.001) than the summer and winter seasons. The result of the current study showed strong positive association between milk yield and temperature-humidity index value with (\(|r| = 0.6 (p < 0.04)\) (Figure 3). Thus, camel milk yield increased with increasing temperature-humidity index between 68.3 and 71.1 minimum and maximum THI value, respectively. In cattle, the milk yield begins to decrease when THI reaches 72 (Du Preez et al., 1990). However, the recent finding in Arizona showed that the milk synthesis in dairying cow reduced when THI exceeds 68 (Jordan, 2003). Disagreeing with the current finding, Bernabucci et al. (2014) revealed significant negative relationships between the milk yield and THI value in high yielding dairying cow.

Contrary to dairying cow, the milk yield increased with the value of THI within the narrow ranges of 68 to 72 THI in dairying camel in the current study. Furthermore, Wheelock et al. (2010) reported a significant reduction of milk yield from heat-stressed cows. Moreover, Aggarwal and Upadhyay (2012) indicated that different livestock species adapted to a different environmental condition have divergent sensitiveness to heat stress. This study shows that camel milk synthesis was considerably affected by season, ambient temperature, and relative humidity. As a result, autumn milk yield was the highest, followed by spring and summer. The variation seems to be related to an insufficient availability of feed and drinking water of the rangeland during the year’s dry period (winter and summer).

3.3. Physicochemical properties of camel milk
The fat content of camel milk varied from 2.0 to 9.2% in dry season and 1.0 to 8.6% in wet season. Lack of variations (p < 0.001) for the fat contents of the evaluated milk samples between dry and wet seasons was unexpected, indicating that season did not affect milk fat concentration. The significant decline in milk fat content during the dry and hot period (under heat stress condition) was reported in cattle trials (Ouellet et al., 2019). Seasonal changes in camel milk fat concentration were more pronounced (Nagy et al., 2017). Moreover, Hammami et al. (2013) revealed a significant decline in milk fat contents from dairy cow subjected to an extreme heat stress. According to Honig et al. (2012), fat concentration from high producing dairy cows subjected to a different cooling session under hot environmental condition shows little variation.

The protein concentration of camel milk in this study showed significant (p < 0.001) decrease during the dry and hot seasons, indicating profound effect of seasons, ambient temperature and relative humidity on milk protein contents. The milk protein concentration of free-ranging camels observed in this study ranged from 1.3 to 3.4% in dry season with the hot environmental condition
and 1.7 to 5.2% during wet season that was manifested by cold-weather condition (Table 3). In agreement to the current finding, Ramón et al. (2016) and Nagy et al. (2017) reported the highest protein concentration of camel milk during winter (wet and cold period) than summer (dry and hot condition). According to Ouellet et al. (2019), heat stress was associated with a significant decline in the milk protein content. The mean protein contents observed in the present finding are in line with the reported by Farah (1993) and Idrees et al. (2016) who described protein constituents of the camel milk that ranging from 2.5 to 4.5%.

The mean casein contents of the analyzed milk samples in the present study were 1.7% in dry and 1.9 during wet seasons and varied (p < 0.001) across seasons. The result of the current finding showed that casein concentrations of camel milk were about 69.1 and 59.6% of protein contents during dry and wet seasons, respectively, indicating the rest of 30.9% in dry and 40.4% during wet season contains whey protein. According to Crowley et al. (2017) and Hughes and Gray (2002), camel milk protein contains casein to whey protein ratio of 73.3–76.2, casein components of milk proteins are sensitive to acidity/alkalies and responsible for milk coagulation at pH 4.6 than whey protein (not affected by acidity). Thus, low casein: whey protein ratio of camel milk than bovine milk might be the reason for low coagulating characteristics. Similarly, Walstra et al. (2005) reported smaller proportions kappa casein (κ-CN) of camel milk than bovine milk. In agreement with the current finding, Hailu et al. (2016) observed shorter gelation time at higher temperature, indicating increasing temperature positively reimbursements for camel milk coagulations’ challenges.

The total solid (TS) and solid-not-fat (SNF) contents of camel milk in this study was higher (p < 0.001) in dry than wet season (Table 3). In the wet season, mean TS and SNF content of the analyzed camel milk was 12.7% and 8.5%, respectively. The SNF contents observed in this study ranging from 4.2% to 9.1% in dry and 5.6% to 11.7% during wet season. The total solid contents observed in this study was comparable with the finding of Idrees et al. (2016) who reported the mean TS concentrations of 13.6% in camel milk. In agreement with the current finding, Nagy et al. (2017) also found the highest TS and SNF concentration during winter (wet and cold period) season.

The finding of the present study showed that the mean lactose concentration in the wet season (4.9%) was higher (p < 0.001) than dry season. In agreement with the current finding, Ahmad et al. (2012) reported higher (p < 0.001) lactose constituent of camel milk during wet season than dry season. The lactose contents of camel milk observed in this study lie within the usual range of 2.9 to 5.8% in the camel milk (Konuspayeva, 2007; Raghvendar et al., 2004). According to Farah (1993), camel milk contained up to 4.4% of lactose. Moreover, about 5.3% of lactose concentration was reported from the camel kept under free-ranging production system (Mostafa et al., 2018).

The current study showed that the average dornic acidity (%D), Thernher acidity (%T), lactic acid, and citric acid of camel milk were higher in dry season than wet season. The mean %D acidity of camel milk in this study was 13.6% in dry and 11.9% in the wet season. The %D acidity value observed in this study at both dry and wet seasons were lower than the range (15–18%D) reported by Carole (2002); M’hamdi et al. (2018) in camel milk and qualified as better quality milk for human consumption, since milk with lower %D acidity value had been classified as better quality (Vázquez-román et al., 2013). The mean pH value of fresh milk observed in dry (6.4) period was lower than wet (7.03) season, indicating the increased acidity of milk during the dry and hot season. The variation might be due to poor forage quality and higher microbial load because of higher temperature in dry and hot season. The average pH value in both seasons were comparable with the report of Khaskheli et al. (2005) and M’hamdi et al. (2018) whose revealed camel milk pH value ranging from 6.57 to 6.97. The mean thernher (%T) acidity value was 15.5 %T in dry season and 13.5 %T during wet season. Similarly, Tasturganova et al. (2018) reported mean %T acidity of 16.5 °T in dromedary camel.
4. Conclusion
This study showed that body temperature, milk physicochemical properties, and the yield of dromedary camels were varied (p < 0.001) with local weather conditions and seasons. The current finding revealed higher diurnal body temperature and high THI max value during the dry and hot season of the year, indicating local weather conditions such as temperature and relative humidity had more likely influence diurnal body temperature of dromedary camels. In the wet season, the dromedary camels milk's chemical properties such as protein, casein, total solid, solid-not-fat, and lactose concentrations were higher (p < 0.001), which is probably associated with better quality and palatable forages accessible in the wet season. In contrast, the milk acidity level during both dry and wet seasons found to be lower than bovine, indicating that the camel is producing the better quality and nutritious milk for human consumption during relatively wet and cold weather condition. Yet, further investigation based on animal trials on at-station is needed in order to confirm the observed free-ranging camel body temperature, milk yield, and physicochemical qualities throughout the lactation period considering the ambient weather condition.

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Data accessibility
The authors declare that all data supporting the findings of this study are available within the article and its supplementary information files.

Animal welfare statement
No ethical approval was required as this is an original data with no sever impacts on animals used for scientific purpose.

Authors contribution
Matiwos Habte - Data curation, Funding acquisition, Investigation, Methodology, Software, Writing-original draft, Writing-review & editing; Mitiku Eshetu (PhD) - Supervision, Validation, Visualization, Project administration, Writing-review & editing; Dereje Andualem (PhD) - Formal analysis, Methodology, Software, Supervision, Validation, Visualization, Writing-review & editing; Melesse Maryo (PhD) - Methodology, Resources, Visualization, Writing-review & editing; Abiyot Legesse (PhD) - Supervision, Validation, Writing-review & editing. Birhanu Admassu - Resources, Visualization

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References
Abate, T. (2016). Indigenous ecological knowledge and pastoralist perception on rangeland management and degradation in Guji Zone of south Ethiopia. Consilience: The Journal of Sustainable Development, 15(1), 192–218. https://doi.org/10.1002/d8q2950
Abdoun, K. A., Samara, E. M., Okob, A. B., & Al-haidary, A. A. (2012). Regional and circadian variations of sweating rate and body surface temperature in camels (Camelus dromedarius). Animal Science Journal, 83(7), 556–561. https://doi.org/10.1111/j.1740-0929.2011.00993.x
Abroulaye, S., Issa, S., Abalo, K. E., & Nouhou, Z. (2015). Perceptions and Adaptation Measures of Crop Farmers and Agro-Pastoralists in the Eastern and Plateau Central Regions of Burkina Faso, West Africa. FREET Journal of Science and Technology, 3(1), 286–298. Firepubs/fjst/3/1/2015/286-298
Adi, S., & Swoboda-reinhold, M. (2003). The Borana Pastoral production and Livelihood system (BPRLS), BLDP/ITZ, Addis Ababa and Negelle/Borana. Pastoral Participatory Extension Concept-PAPOEC documents worked out compiled during consultant mission of Boris Schiele–September/October. Addis Ababa.
Aggarwal, A., & Upadhyay, R. (2012). Heat stress and animal productivity. Springer Science & Business Media.
Ahmad, S., Yaqoob, M., Bilal, M. O., Khan, M. K., Muhammad, G., Yang, L.-G., & Tariq, M. (2013). Factors affecting yield and composition of camel milk kept under desert conditions of central Punjab, Pakistan. Tropical Animal Health and
Habte et al., Cogent Food & Agriculture (2021), 7: 1930932
https://doi.org/10.1080/23311932.2021.1930932

Production, 44(7), 1403–1410. https://doi.org/10.1007/s11250-012-0079-3

Al-Haj, O. A., & Al-Kanhal, H. A. (2010). Compositional, technological and nutritional aspects of dromedary camel milk. International Dairy Journal, 20(12), 811-821. https://doi.org/10.1016/j.idairyj.2010.04.003

Al-faraj, A. A., & Al-Haidary, A. A. (2001) Measurement and simulation of camel core body temperature response to ambient temperature. Livestock Environment VI, Proceedings of the 6th International Symposium (21-23 May 2001, Louisville, Kentucky, USA) ed. Richard R. Stowell, Ray Bucklin, and Robert W. Bottcher. https://doi.org/10.13031/2013.7090

Al-Haidary, A., Samara, E., Okab, A., & Abdoun, K. (2013). Thermophysiological responses and heat tolerance of Saudi camel breeds. International Journal of Chemical Environment of Biology Science, 1(1), 173–176.

Ahmashry, A., Fenta, A. A., Yasuda, H., Kimura, R., & Shimizu, K. (2019). Seasonal Rainfall Variability in Ethiopia and Its Long-Term Link to Global Sea Surface Temperatures. Journal of Water, 12(1), 55. https://doi.org/10.3390/w12010055

Ali-Jassim, R., & Sejiri, D. A. (2015). Climate change and camel production: Impact and contribution. Journal of Camelid Science, 8, 1–17.http://www.isocard.net/en/journal

Barbano, D., Wojciechowski, K., & Lynch, J. (2010). Effect of preservatives on the accuracy of mid-infrared milk component testing. Journal of Dairy Science, 93(12), 6000–6011. https://doi.org/10.3168/jds.2010-3601

Bernabucci, U., Biffoni, S., Buggiatti, L., Vitali, A., Locetere, N., & Nardone, A. (2014). The effects of heat stress in Italian Holstein dairy cattle. Journal of Dairy Science, 97(1), 471–486. https://doi.org/10.3168/jds.2013-6611

Bitman, J., Lefcourt, A., Wood, D., & Stroud, B. (1984). Circadian and ultradian temperature rhythms of lactating dairy cows. Journal of Dairy Science, 67(5), 1014–1023. https://doi.org/10.3168/jds.S0022-0302(84)81400-9

Bouraoui, R., Lahmar, M., Mejda, A., Djemiali, M., & Belyea, R. (2002). The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. Animal Research, 51(6), 479–491. https://doi.org/10.1051/animres:2002036

Carole, L. (2002). Science et technologie du lait: Transformation du lait. Presses internationales Polytechnique.

Chee, J. D. (2013). Pearson’s Product-Moment Correlation: Sample Analysis. University of Hawaii at Manoa School of Nursing.

Collier, R. J., Beede, D., Thatcher, W., Israel, L., & Wilcox, C. (1986). Influences of environment and its modification on dairy animal health and production. Journal of Dairy Science, 69(1), 2213–2227. https://doi.org/10.3168/jds.S0022-0302(86)82848-3

Crowley, S. V., Kelly, A. L., Lucey, J. A., & O’ Mahony, J. A. (eds.). (2017). Potential Applications of Non-Bovine Mammalian Milk in Infant Nutrition. John Wiley & Sons, Ltd.

Dereje, M., Urge, M., Animut, G., Kurtu, M. Y., & Tilahun, S. (2016). Effect of concentrate supplementation to free ranging dromedary camels on yield, physicochemical quality and fatty acid profile of milk. Livestock Research for Rural Development, 28(6). http://www. lrrd.org/lrrd28/6/dere28099.html

Dikmen, S., & Hansen, P. (2009). Is the temperature-humidity index the best indicator of heat stress in lactating dairy cows in a subtropical environment? Journal of Dairy Science, 92(1), 109–116. https://doi.org/10.3168/jds.2008-1170

Du Preez, J., Hattingh, P., Giesecke, W., & Eisenhower, B. (1990). Heat stress in dairy cattle and other livestock under southern African conditions. III. Monthly temperature-humidity index-mean values and their significance in the performance of dairy cattle.

Duncan, B. D. (1955). Multiple range and multiple F tests. Biometrics, 11(1), 1–42. https://doi.org/10.2307/3001478

Farah, Z. (1999). Composition and characteristics of camel milk. Journal of Dairy Research, 60(4), 603–626. https://doi.org/10.1017/S0022-1167000100228

Faraz, A. (2020). Food security and socio-economic uplift of camel herders in Southern Punjab, Pakistan. Land Science, 2(2), 8–11. https://doi.org/10.30560/lvs.nv2p8

Faraz, A., Waheed, A., Mirza, R. H., & Ishaq, H. M. (2019a). The camel – A short communication on classification and attributes. Journal of Fisheries Livestock and Production, 7(1), 289. https://doi.org/10.1472/2332-2608.1000289

Faraz, A., Waheed, A., Mirza, R. H., & Ishaq, H. M. (2019b). Role of camel in food security: A perspective aspect. Journal of Fisheries Livestock and Production, 7(1), 290. https://doi.org/10.1472/2332-2608.1000290

Faraz, A., Waheed, A., Mirza, R. H., & Ishaq, H. M. (2019c). Socio economic status and associated constraints of camel production in desert Thal Punjab. Pakistan Journal of Fisheries Livestock and Production, 7(1), 288. https://doi.org/10.1472/2332-2608.1000288

Faraz, A., Waheed, A., Mustafa, A. B., Touqir, N. A., Mirza, R. H., Ishaq, H. M., & Nabeel, M. S. (2021). Milk production potential of Marecha camel (Camelus dromedarius) in extensive and semi-intensive management systems. Pakistan Journal of Zoology, 53(1), 273–280. https://dx.doi.org/10.17582/jpzo/20200227090212

Faraz, A., Waheed, A., Mustafa, A. B., Touqir, N. A., & Mustafa, A. B. (2020). Milk production variations between rear and fore udder-halves in Barela dromedary camel. Journal of Saudi Society of Agricultural Science,20(1), 48-51. https://doi.org/10.1016/j.jssas.2020.11.002

Gomez, K. A., & Gomez, A. A. (1984). Statistical procedures for agricultural research. John Wiley & Sons.

Hollu, Y., Hansen, E. B., Seifu, E., Eshtu, M., & Ipsen, R. (2016). Factors influencing the gelation and rennetability of camel milk using camel chymosin. International Dairy Journal, 60, 62–69. https://dx.doi.org/10.1016/j.idj.2016.01.013

Hosseini, H., Bormann, J., M’hamdi, N., Montaldo, H. H., & Gengler, N. (2013). Evaluation of heat stress effects on production traits and somatic cell score of Holsteins in a temperate environment. Journal of Dairy Science, 96(3), 1844–1855. https://doi.org/10.3168/jds.2012-5947

Honig, H., Miron, J., Lehrer, H., Jackoby, S., Zachut, M., Zinov, A., Portnick, Y., & Moalem, U. (2012). Performance and welfare of high-yielding dairy cows subjected to 5 or 8 cooling sessions daily under hot and humid climate. Journal of Dairy Science, 95(7), 3736–3742. https://doi.org/10.3168/jds.2011-5054

Hughes, C., & Gray, I. (2001). Chemical Analysis in the New Zealand Dairy Industry. Chemical Processes in New Zealand. 11.

Idrees, E. M., Ishaq, I. A., & Eisa, M. O. (2016). Factors affecting chemical properties of camel milk. Scientia, 16(2), 49–53. https://doi.org/10.15192/PSC.PSA.2016.16.2.4953

Ispema, A., Konse, D., Hogewerf, P., Houwers, H., & Van Roest, H. (2008). Pilot study to monitor body temperature of dairy cows with a rumen bolus. Computers and Electronics in Agriculture, 64(1), 49–52. https://doi.org/10.1016/j.compag.2008.05.009
Jordan, E. (2003). Effects of heat stress on reproduction. Journal of Dairy Science, 86, E104–E114. https://doi.org/10.13140/RG.2.2.13493.67141

Kassambura, A. (2018). ggpubr: “ggplot2” based publication ready plots. R package version 0.1.1.

Kendall, P., Tucker, C., Dolley, D., Clark, D., & Webster, J. (2006). Milking frequency affects the circadian body temperature rhythm in dairy cows. Livestock Science, 112(1–2), 130–138. https://doi.org/10.1016/j.livsci.2007.12.009

Khasheli, M., Arain, M., Chaudhry, S., Soomro, A., & Qureshi, T. (2003). Physico-chemical quality of camel milk. Journal of Agriculture and Social Sciences, 1(2), 164–166. 1813–2235/2005/01–2–164–166

Kononosyev, G. (2007). Variabilité physico-chimique et biochimique du lait des grands camélidés (Camelus bactrianus, Camelus dromedarius et hybrides) au Kazakhstan. Université Montpellier II, France, 89.

Lefcourt, A. M., & Adams, W. (1998). Radiotelemetric measurement of body temperature in feedlot steers during winter. Journal of Animal Science, 76(7), 1830–1837. https://doi.org/10.2527/1998.761830x

Liang, D., Wood, C., McQueeny, K., Roy, D., Clark, J., & Bewley, J. (2012). Influence of breed, milk production, season, and ambient temperature on dairy cow rectal temperature. Journal of Dairy Science, 96(8), 5072–5081. https://doi.org/10.3168/jds.2012-6537

Mhamdi, N., Bouraoui, R., Darej, C., Mahjoub, A., Hassayounne, L., Mhamdi, H., & Lanouari, L. (2019). The Effect of Storage Temperature and Duration on the Composition and Bacteriological Quality of Raw Milk. Journal of Agriculture and Allied Sciences, 7(1), 77–82.

Madsen, T., Nielsen, M., Andersen, J. B., & Ingvarsens, K. L. (2008). Continuous lactation in dairy cows: Effect on milk production and mammary nutrient supply and extraction. Journal of Dairy Science, 91(5), 1791–1801. https://doi.org/10.3168/jds.2007-0905

Mostafa, T., El-malky, O., Abd El-salam, A., & Nobih, A. (2018). Milk production and composition in Maghrebian she-camel under different management system in Egypt. Journal of Agriculture and Veterinary Science, 11(11), 29–37. https://doi.org/10.9790/2380-1101012917

Nagy, P., Fábi, Z. N., Varga, L., Reiczigel, J., & Juhasz, J. (2017). Effect of genetic and nongenetic factors on chemical composition of individual milk samples from dromedary camels (Camelus dromedarius) under intensive management. Journal of Dairy Science, 100(11), 8680–8693. https://doi.org/10.3168/jds.2017-12814

NMA. (2015). Seasonal agro meteorological bulletin. Kiremt Seasonal Outlook for Ethiopia. Addis Ababa: National meteorological Agency.

Ouellet, V., Cabreiro, V., Fadul-pacheco, L., & Carbonneau, E. (2012). The relationship between the number of consecutive days with heat stress and milk production of Holstein dairy cows raised in a humid continental climate. Journal of Dairy Science, 2029(9), 8537–8545. https://doi.org/10.3168/jds.2018-16060

Pragnn, P., Archana, P., Aleena, J., Sejin, V., Krishnan, G., Bagath, M., Manimaran, A., Beena, V., Kurien, E., & Varma, G. (2017). Heat stress and dairy cow: Impact on both milk yield and composition.

Raghvendrar, S., Shukla, S., Sohani, M., & Bhakat, C. Chemical and physicochemical properties of camel milk at different stages of lactation. International Conference, Saving the Camel and peoples Livelihoods, Sadri, Rajasthan, India, 2004.

Ramón, M., Díaz, C., Pérez-guzman, M., & Carabaño, M. (2016). Effect of exposure to adverse climatic conditions on production in Manchega dairy sheep. Journal of Dairy Science, 99(7), 5764–5779. https://doi.org/10.3168/jds.2016-10909

Ravagnolo, O., & Mislitz, I. (2002). Effect of heat stress on nonreturn rate in Holstein cows: Genetic analyses. Journal of Dairy Science, 85(11), 3092–3100. https://doi.org/10.3168/jds.2002-0302(02)74396-8

Renaudeau, D., Collin, A., Yahav, S., De Bassiolo, V., Gourdine, J. L., & Collier, R. (2012). Adoption to hot climate and strategies to alleviate heat stress in livestock production. Animal: An International Journal of Animal Bioscience, 6(5), 707. https://doi.org/10.17177/1751731111002488

Rhoads, M., Rhoads, R., Vanbaale, M., Collier, R. J., Sanders, S., Weber, W., Crocker, B., & Baumgard, L. (2009). Effects of heat stress and plane of nutrition on lactating Holstein cows: I. Production, metabolism, and aspects of circulating somatotropin. Journal of Dairy Science, 92(5), 1986–1997. https://doi.org/10.3168/jds.2008-1641

Riek, A., & Gerken, M. (2006). Changes in llama (Lama glama) milk composition during lactation. Journal of Dairy Science, 89(8), 3484–3493. https://doi.org/10.3168/jds.2002-020(06)72387-6

SAS. (2017). SAS/STAT® 14.3 User's Guide: High-Performance Procedures.

Schmidt-nielsen, K., Schmidt-nielsen, B., Jornum, S., & Houpt, T. (1956). Body temperature of the camel and its relation to water economy. American Journal of Physiology, 188(1), 103–112. https://doi.org/10.1152/ajplegacy.1956.188.1.103

Schüller, L., Burfeind, O., & Heuwieser, W. (2014). Impact of heat stress on conception rate of dairy cows in the moderate climate considering different temperature–humidity index thresholds, periods relative to breeding, and heat load indices. Theriogenology, 81(8), 1050–1057. https://doi.org/10.1016/j.theriogenology.2016.01.029

Shack, D., Leblanc, S., Leslie, K., Hand, K., Godkin, M., Coe, J., & Kelton, D. (2016). Studying the relationship between on-farm environmental conditions and local meteorological station data during the summer. Journal of Dairy Science, 99(3), 2169–2179. https://doi.org/10.3168/jds.2015-9795

Sisay, F., & Awoke, K. (2015). Review on production, quality and use of camel milk in Ethiopia. Journal of Fisheries Livestock and Production, 3(2), 145. https://doi.org/10.4172/2322-2608.1000145

Tasturganova, E., Dikhanbaeva, F., Prosekov, A., Zhunusova, G., Dzhepisbaeva, B., & Matibeova, A. (2018). Research of fatty acid composition of samples of bio-drink mode of camel milk. Current Research in Nutrition and Food Science Journal, 6(2), 491–499. https://doi.org/10.12944/CRNSJ1.6.2.23

Upadhyay, N., Goyal, A., Kumar, A., Ghot, D. L., & Singh, R. (2014). Preservation of milk and milk products for analytical purposes. Food Reviews International, 30(3), 203–224. https://doi.org/10.1080/08785912.2014.931392

Vázquez-román, S., García-lara, N. R., Escuder-vieco, D., Chaves-sánchez, F., De La Cruz-bertola, J., & Pallas-aloons, C. R. (2011). Determination of dornic acidity

https://doi.org/10.1080/23311932.2021.1930932
as a method to select donor milk in a milk bank. 
Breastfeeding Medicine, 8(1), 99–104. https://doi.org/10.1089/bfm.2011.0091

Walstra, P., Walstra, P., Wouters, J. T., & Geurts, T. J. (2005). Dairy science and technology. CRC press.

Wheelock, J., Rhoads, R., Vanbaale, M., Sanders, S., & Baumgard, L. (2010). Effects of heat stress on energetic metabolism in lactating Holstein cows. 
Journal of Dairy Science, 93(2), 644–655. https://doi.org/10.3168/jds.2009-2295

Yohannes, M., Zeleke, M., & Gebru, G. (2007). Potentials of camel production in Babilie and Kebribeyah woredas of the Jijiga zone, Somali region, Ethiopia. Livestock Research for Rural Development, 19(4). http://www.lrrd.org/lrrd19/4/meha19058.htm