EFFECTS OF INCLUSION OF *OPUNTIA STRICTA* (ERECT PRICKLY PEAR) IN THE DIET OF LACTATING CAMELS ON MILK PRODUCTION AND QUALITY IN KENYA

BY

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This thesis is my original work and has not been presented for award of degree in any other university.

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DEDICATION

I dedicate this work to my parents and siblings for their priceless support and love.

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LIST OF ABREVIATIONS AND ACRONYMS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
ASALs	Arid and Semi-Arid Lands
Ca	Calcium
CF	Crude Fiber
CP	Crude Protein
CSC	Cotton seed Cake
DM	Dry Matter
EE	Ether Extract
IVDMD	*in vitro* Dry Matter Digestibility
NDF	Neutral Detergent Fiber
NDS	Neutral Detergent Solubles
O. stricta	*Opuntia*
P	Phosphorus
SNF	Non- Fat Solids
SPSS	Statistical Package for Social Sciences

ABSTRACT

There are increasing numbers of pastoralist communities rearing camels in the Arid and Semi-Arid Lands of Kenya, whose population in the country was estimated to be 3.22 million in 2016. The camel keepers experience shortage of fodder especially during prolonged drought. Within these ASALs, *Opunti*a is regarded as an invasive species. *Opuntia* is drought-resilient, tolerates severe utilization and provide large quantities of succulent fodder to camels during prolonged drought. The study therefore evaluated the effects of inclusion of *Opuntia stricta* (erect prickly pear) in diets of lactating camels on milk production and milk composition. Eight lactating dromedary Somali camels were kept under traditional management conditions and supplemented with *Opuntia stricta* and cotton seed cake in a double Latin Square experimental design for 84 days. The four treatments were: grazing only (control); grazing supplemented with *Opuntia stricta* only; grazing supplemented with *Opuntia stricta* plus Cotton seed cake; grazing supplemented with Cotton seed cake only. Specific objectives were to determine the most preferred forage species by camels and their nutritional value, evaluate the chemical composition and *in vitro* dry matter digestibility of *Opuntia stricta* as well as explore the effects of supplementing lactating grazing camels with *Opuntia stricta* and cotton seed cake on milk yield, composition and sensory characteristics. The most preferred browsed and grazed forage species were; *Acacia nubica* (22.6%), *Acacia seyal* (47.3%), *Cucumis aculeatus* (7.2%), *Euclea divinorum* (11.1%), *Hibiscus parrifolia* (11.9%) during wet season. Additionally, *Barleria acanthoides* (22.9%), *Balanites aegyptiaca* (15.5%), *Cynodon dactycon* (11.7%), *Lycium europium* (32%), *Pollichia campestris* (17.8%) were the most browsed and grazed forages in the dry season. Among camels fed on the supplemental diets, there was a highly significant difference (P<0.001) in crude protein intake with camels fed on the cotton seed cake diet having the highest (0.414±0.018 kg) and *Opuntia stricta* diet having the least (0.061±0.003 kg) crude protein intake per day respectively. There was no difference in dry matter intake between camels fed on different supplemental diets ($P > 0.05$) and ranged between 1.416±0.055-1.626±0.051 kg/day. Milk yield ranged between 4.49 and 4.82 L/day and there were no differences among treatments. Similarly, Milk composition () was also not affected by the treatments ($P > 0.05$). On sensory attributes, appearance, flavor, mouth feel and smell were not significantly different ($P > 0.05$) while there were significant differences in acceptability and preference among camels on different treatments ($P<0.05$). Milk from camels supplemented with *Opuntia stricta* and cotton seed cake was more preferred and acceptable among panelists than other treatments. The study concluded that camels preferred the forage species that had high crude protein and low neutral detergent fibre. Young cladodes were nutritious than the mature ones and *Opuntia stricta* was highly digestible. The study recommended further research should be done on optimal level of *Opuntia stricta* supplementation to grazing lactating camels.

Keywords: *Opuntia stricta*; milk yield; Cotton seed cake; preferred forages; lactating camels

CHAPTER 1

1 GENERAL INFORMATION

1.1 Background of study

In Kenya, the Arid and semi-arid lands (ASALs) covers more than 89% of land (United Nations Development Programme (UNDP), 2018). The ASALs supports 30% of Kenya's population (about 16million) covering 29 counties (KNBS, 2019). These are areas which have been marginalized and regarded as unproductive, with media reports on cattle rustling, drought, insecurity and poverty masking the potential of these regions. These areas have been affected greatly by climate change increasing land degradation, poverty, food insecurity and human being conflict. ASALs are occupied by pastoralists who rely on livestock keeping for drought insurance, means of transport, cash flow, source of food, social status and wealth (Abdela *et al.*, 2001; Guliye *et al.*, 2007; MOLD, 2010; Mahmoud, 2011).

In the recent past, water shortages due to climate change have led to loss of livestock, especially cattle. This has led to decreased meat and milk production devastating pastoralist's livelihoods therefore increasing insecurity and conflicts (Opiyo *et al.*, 2014).

Prolonged drought leads to deterioration in livestock quality and in the long run, increases mortality. In Kenya, it is estimated that over 25% of livestock populations in ASAL areas are lost due to water and pasture scarcity on annual basis (Government of Kenya (GOK), 2017). Twenty eight droughts have been recorded in Kenya for the past 100 years with the last 20 occurring in the last 50 years (Republic of Kenya, 2017). Three million people, majority being pastoralists, were left in need of emergency food aid during such times (Watete *et al*., 2016). In 2017, in the North and North Eastern parts of Kenya, small livestock such as goats, sheep and larger livestock like camels and cattle were lost due to prolonged drought (Republic of Kenya, 2017).

To address this challenge, it is important to strengthen the adaptive capacity of pastoralists in these areas prone to drought by providing readily available fodder for livestock so as to stabilize their livelihoods. *Opuntia stricta* is the most frequently browsed forage species, both during wet and dry season with the highest *in vitro* dry matter digestibility (Gebremedhn, 2018). The utilization of *Opuntia stricta* is much higher in camels than in any other animal (FAO, 2017).

The species has high dry matter digestibility of 65-70%, are rich in water soluble carbohydrates of 45-55% but low crude protein (3-7%) (Chiteva & Wairagu, 2013). Since the low protein content limits use of cactus, supplementation with a protein source, makes it a complete meal, especially for ruminant animals (Dubeux, 2010; Lopes, 2018). The study therefore evaluated the effects of inclusion of *Opuntia stricta* in the diet of lactating camels on milk production and quality.

1.2 Statement of the problem

In the past few decades, longer and less predictable droughts have been recorded in Kenya accompanied by an increasing trend on the country's average temperatures. As a result, droughts are frequent phenomena in ASAL areas and pastoralists must learn to cope. During droughts, animals die in large numbers due to depletion of pasture with cattle and sheep being the first to succumb, followed by goats. The most resilient are the camels that can survive for up to 14 days without water, whereas cattle and sheep only survive a few days.

The Government agencies in collaboration with Non-governmental organizations have encouraged the keeping of camels in ASALS to promote adaptation to the longer and less predictable droughts. As a result, there is a growing number of Kenyans keeping camels in ASALS. The country's camel population was estimated to be 4.8 million in 2019.

It is not clearly known when cactus was introduced in Kenya but some reports show that *Opuntia stricta* and *Opuntia ficus-indica* were introduced in the dry areas of Central Kenya and Rift valley by colonial administrators in the 1940's. They were used as ornamental hedge plants to shield homesteads and agricultural fields from wild animals which roamed the land and were known as cactus fence. Once the *Opuntia* hedge is established, it is difficult to control its spread, since cut or broken fragments of the stem readily take root when they fall to the ground and form another hedge. Furthermore, the cactus fruit seeds can persist in the soil for at least 19 months and easily germinates with minimal rainfall.

Consumption of cactus fruit by birds, domestic herds and wild animals such as elephants and baboons aid the dispersal of cactus seeds. Since the cactus is not native to Kenya and therefore had no natural predators, with time it invaded the grazing rangelands that were typically used by pastoralists. Climate change issues such as prolonged droughts, changes in land use primarily settlement of pastoralists, followed by overgrazing and subsequent land degradation, made the highly drought resistant cactus flourish and become aggressively invasive, covering hundreds of acres of land in the rangelands with negative environmental impacts. Currently *Opuntia* is regarded as the second highest elephant killer in Kenya, and also kills approximately 500 goats annually while others are left toothless. In goats and elephants, the glochids get stuck between their teeth, causing them to rot and fall off leaving the animal toothless and unable to feed *Opuntia* is a common feed for livestock in the ASALs regions of the world as it's survives in dry climatic environments and still remains productive and nutritious. It can be utilized both as a feed supplement and a source of water. Many studies have evaluated the effects of *Opuntia* on cows, ewes, goats and sows. However, the utilization of *Opuntia* in the diets of lactating camels on milk production and quality is not well documented. Therefore, the study evaluated the effects of inclusion of Opuntia stricta in the diets of lactating camels on milk quantity and quality.

1.3 Justification

Mitigating against loss of livestock during extended drought periods will enhance sustainable development. This can be attained by promoting pastoralists' transition to different types of production systems, increasing their adaptive capacity, coping strategies and resilience to environmental hazards (Muricho *et al.*, 2018). Camel keeping is crucial in combating climate change impacts, perennial food insecurity and changing livelihoods through the sale of surplus camel milk, which is better priced than cow milk. To address the challenge of lack of pasture during prolonged drought, there is the need to utilize a fodder resource that is adapted and abundant in the ASALS as a kind of 'Drought-Insurance' in these regions.

Cactus withstands high temperatures, water shortage and poor soil fertility and is thus adapted in ASALs of the world (Syomiti *et al.*, 2014). It spreads and forms large colonies in dry seasons. Cactus is regarded as "bank of life" in water scarce areas as it provides water for both humans and animals (Salem, 2010).

In this study, the use of *Opuntia stricta* as a supplement for lactating grazing camels was evaluated as a single supplement or enriched with a protein source. The main performance indicators were the quantity and quality of milk produced.

1.4 Objectives

1.4.1 Broad objective

To evaluate the effects of dietary supplementation with *Opuntia stricta* and a protein source on milk yield, quality and acceptability of lactating Somali camels

1.4.2 Specific objectives

The specific objectives were to:

1. Determine the most preferred forage species by grazing Somali camels in Laikipia County and assess the effect of seasonality on forage preference.
2. Evaluate the nutritional value and digestibility of *Opuntia stricta* at different stages of growth.
3. Determine the effects of supplementing lactating grazing camels with *Opuntia stricta* and cotton seed cake on milk quantity and quality.
4. Assess the acceptability of milk from grazing Somali camels supplemented with *Opuntia stricta* and cotton seed cake.

1.5 Null Hypothesis

1. There are no significant differences on the forage preference of camels and effect on seasonality
2. There are no differences in the nutritional value and digestibility of *Opuntia stricta* at different stages of growth
3. There are no differences in milk quantity and quality between grazing lactating camels and those supplemented with *Opuntia stricta* and cotton seed cake
4. There are no differences in acceptability of camel milk between the grazing Somali camels and those supplemented with *Opuntia stricta* and cotton seed cake

CHAPTER 2

2 LITERATURE REVIEW

2.1 Camel (*Camelus dromedaries*)

2.1.1 Overview of camel production

Determination of the exact number of camels in the world is very difficult. First off, they are not subjected to obligatory vaccination. Secondly, camels are owned by pastoralists and nomads who are always on the move (Faye, 2014). As such, it is difficult to report an in-depth census for the camel population. The world's camel population is therefore estimated as 27 million and with Africa comprising of 15 million (Guliye *et al*., 2007;Faye, 2014; Schwartz, 2014). One-humped dromedary camels are estimated as 17 million of the world's camel population while two-humped Bactrian camels are estimated as 2 million (Farah *et al.*, 2007). A third of the world's dromedary camels are reported to be from Somalia, with over 6 million camels; which is regarded to have the largest camel population in the world (Farah *et* al., 2007; Schwartz, 2014). Kenya consists of 7.5% of the world's camel population ranked as the fourth after Somali, Sudan and Ethiopia. This comprises of 99% of camels in the Greater Horn of Africa. Besides Africa, camels are also found in Middle East countries in the Asian continent.

In the past, camels were mainly found in the North Eastern regions of Kenya owned by Somali people but later spread to Gabbra and Rendille communities in Marsabit County (Kagunyu & Wanjohi, 2014). Due to recurrent prolonged drought in ASAL areas, camels have increasingly replaced cattle among the Borana, Turkana, Maasai, Pokot and Samburu communities as a climate adaptation strategy as well as increased demand for camel milk due to the associated health benefits (Guliye *et al*., 2007; Opiyo *et al*., 2015; Watson *et al.*, 2016). Baird *et al.* 2014 reported loss of approximately 70% of cattle, goat and sheep during 2005-2006 drought. Up to 2,300 (approximately 0.2%) of the Kenya's camel population is found in Laikipia county, which is mainly Somali breed. In Kenya, camels are named after the community and consists of only three breeds, mainly; Somali, Rendille and Turkana breeds (Kimenye, 2008). The estimated camel population by county in Kenya is shown in Table 2.1.

Table 2:1: Camel population in Kenya by County

Counties	**Camels numbers**	**% composition**
1. Traditional camel keeping counties		
Garissa	489,648	16
Isiolo	68,000	2.22
Mandera	596,863	19.51
Marsabit	224,000	7.32
Tana River	61,992	2.03
Turkana	832,462	27.21
Wajir	717,028	23.43
Sub Total	**2,989,993**	**97.72**
2. Emerging camel keeping counties		
Baringo	10,726	0.35
Laikipia	8,072	0.26
Samburu	37,145	1.21
Taita Taveta	3,320	0.11
West Pokot	5,850	0.19
Sub Total	65,113	2.13
Total (Main Camel keeping counties)	**3,055,106**	**99.85**
3. Counties with <1000 camels	4,734	0.15
Country Total	**3,059,840**	**100**

Source: (Gikonyo *et al*., 2018).

2.1.2 Camel Milk Production

The country's camel population was estimated at 4.6 million in 2019, with annual milk production of 940 million liters (KNBS, 2019). Laikipa county is reported to produce approximately 0.3 % of Kenya's camel milk (Kimenye, 2008). However, about 50% of the camel milk goes to waste and only 12% is marketed while 38% is consumed by the camel owners and their herders as food. Of the 12% marketed camel milk, only 2% gets to the urban consumers, 10% is sold to local consumers in raw form (Akweya *et al*., 2012). In comparison to the fresh milk which sells at a good price, fermented camel milk sells at half price bringing less income to farmers (Noor, 2013). Commercialization of camel milk would therefore, increase income from the surplus camel milk during the rainy season for the camel keeping communities (Akweya *et al.*, 2012; Elhadi *et al.*, 2015).

The ASALs environment has scarce water resources therefore pastoralists have to 'dry milk" (Akweya *et al*., 2012). Studies by Wanjohi *et al*. (2010) and Maitha *et al*. (2019) reported presence of *Staphylococcus aureus*, a milk pathogen in camel milk. Regardless, pastoralists still consume raw camel milk exposing themselves to health risks such as antimicrobial resistance, zoonotic and food borne diseases; brucellosis and salmonellosis (Fazlani *et al*., 2011; Kaindi *et al*., 2011; Shimol *et al*., 2012; Garcell *et al*., 2016).

During harsh climatic conditions, camels tend to produce more milk and for a longer duration comparable to other livestock (Bekele *et al*., 2002; Farah *et al*., 2007). Field & Kariuki, (2005) reported that a camel produces six times more milk than indigenous cattle. It is difficult to quantify the actual camel milk yield because of the off-take by the calves for growth and survival.

Camel milk production is influenced by season, water availability, breed, milking frequency, stage of lactation, feed quality and quantity (Bekele *et al*., 2002; Mario *et al*., 2008; Bekele *et al*., 2011; Babiker & El-zubeir, 2014; Shuiep, 2014). Under pastoralists' milking practices, the average daily milk yield per camel has been reported to range from 0.5–8L, 3–7.62L, 3-10L and 2-6L respectively with 12-18 months lactation period (Gizachew & Tadesse, 2014;Gebremichael *et al*., 2019). Shuiep, (2014) reported that camel's milk yield decreased with water deprivation for a period of more than two weeks. Studies by Bekele (2010) reported that camels may drink just once in average of 10 days during very hot climatic conditions and lose less than 30% live weight when dehydrated. In Sahara region, camels may take 6 to 7 months without water during cool season even when water is offered to them. According to Bekele *et al*., (2011), camels do not dilute milk under dehydration which is contrary to widespread belief.

Milk frequency depends on the feed availability, season, and pastoral society (Gebremichael *et al*., 2019). State, (2015) reported milk yield of 2 to 5L for an East Africa camel when milked 3 to 4 times a day (Table 2.2). Under pastoral practices in Eastern Ethiopia, camels are milked 1-4 times a day while in Somalia, milking is done 1-5 times a day (Bekele *et al.,* 2002; Kebede *et al*., 2015).

On the contrary, majority (67%) of the camel herders in Ethiopia milk their camels twice a day-morning and evening, whereas 33% of the households milk three times a day (Farah *et al*., 2007; Gebremichael *et al*., 2019). For optimal milk yield, milking should be done four to six times a day (Wernery *et al*., 2004).

The milk yield of camels from various countries are reported in Table 2.2.

Table 2.2 Milk yields of camels reported from various countries

Country	Average daily yields in Kg	Lactation length in months	Calculated yield in Kg per 365 days
Algeria	4	9 – 16	1460
Ethiopia	5	12 – 18	1825
India	6.8	18	2482
Kenya	4.5	11 – 16	1643
Pakistan	8	16 – 18	2920
Somalia	5	9 – 18	1825
Tunisia	4	9 – 16	1460

Source: (FAOSTAT, 2018)

The camel is estimated to have 9-18 months lactation period with an average of 12 months (Ramet, 2001;Bekele *et al*., 2002). The duration of lactation is influenced by calf's survival.

In Kenya, pastoralists believe in camel numbers rather than the milk yield potential of the camel. Camels are therefore reared for subsistence instead of commercial production, reporting milk yield below their genetic potential (Kagunyu & Wanjohi, 2014). According to a study by Onjoro *et al*. (2004), camel milk production can increase to more than 10 liters of milk yield per day with better feeding. Pastoral communities consume milk either as fermented milk or raw milk contributing up to 30% of annual caloric intake in their nutrition (Farah et al., 2007; Elhadi et al., 2015).

2.1.3 Camel milk composition

Composition of milk of a camel differs from other species as shown in Table 2.3 (Guliye *et al*., 2000; Ramet, 2001; Kanhal and Hamad, 2010). This can influence the acceptability and preference of camel milk in relation to other types of milk such as cow milk and goat milk.

Table 2:3: Chemical composition of milk of various species

Proximate	Water %	Protein %	Fat %	Ash %	Lactose %
Camel	86-88	3.0-3.9	2.9-5.4	0.6-0.9	3.3-4.4
Cow	85-87	3.2-3.8	3.7-4.4	0.7-0.8	4.8-4.9
Buffalo	82-84	3.3-3.6	7.0-11.5	0.8-0.9	4.5-5.0
Sheep	79-82	5.6-6.7	6.9-8.6	0.9-1.0	4.3-4.8
Goat	87-88	2.9-3.7	4.0-4.5	0.8-0.9	3.6-4.2
Human	88-89	1.1-1.3	3.3-4.7	0.2-0.3	6.8-7.0

Source: (Kanhal and Hamad, 2010).

Camel milk is opaque white in color, with sharp taste and a slight sweet scent (Abbas *et al*., 2013). The camel milk fat globules are homogenized uniformly throughout the milk giving it opaque white color (Yadav *et al*., 2015). Moreover, it has the smallest fat globules (2.99 μm) compared to (3.19 μm) of goat milk (Mansson, 2008). The taste can be from sharp to sweet or salty which is influenced by type of feed, stage of lactation, quantity and quality of drinking water a ailable (Farah & Fischer, 2004; Farah, 2017). In the early stage of lactation, camel milk has relatively high lactose content hence has a sweeter taste in comparison to subsequent stages of lactation. (Zekele, 2007; Riyadh *et al*., 2012). It can be kept longer than cow milk without refrigeration because it sours slowly but easily ferments to yoghurt after souring (Farah & Fischer, 2004; Field & Kariuki, 2005).

Camel milk composition varies with the feeding conditions, season, camel's health status, stage of lactation, genetics, and parity (Konuspayeva *et al*., 2009; Elhassan*et al*., 2015). Generally, camel milk ranges between 3.5-4.3%fat, 3.1-3.4%protein, 11.9-13.1% total solids, 0.97%ash, 1%density, 8.5-8.9% solids not fat and 4.4-4.7% lactose (Al haj and Al Kanhal, 2010; El-zubeir, 2014;Elhassan *et al.*,2015). Kanhal and Hamad (2010) study reported an average of 3.4% milk protein, 3.5% milk fat, 4.4% milk lactose, 87% water content and 0.79% ash. Camel milk has a lower pH (6.2-6.5) and milk density (1.026-1.035) compared to cow's milk with a maximum buffering capacity of pH 4.95 (Farah & Fischer, 2004;Gul *et al*., 2015). Dromedary camel milk contains 3-3.9% protein (Gebremichael *et al*., 2019).

Camel milk contains two main groups of proteins (caseins and whey proteins) and relatively higher amount of immune proteins (Peptidoglycan Recognition Protein, Lactoferrin Lysozyme and Lactoperoxidase) and insulin (Abbas *et al*., 2013;Gul *et al*., 2015). Camel milk is a good substitute for human milk as it does not contain *beta*-lactoglobulin, a common allergen characteristic of ruminant's milk (Tessema, 2015). The level of dromedary camel milk fat is believed to be 2.9-5.4 % and can be reduced from 4.3% to 1.1% in the milk of dehydrated camels (Konuspayeva *et al*., 2009; Gebremichael *et al*., 2019). A recent study reported camel milk to contain only 2% fat which are mainly composed of polyunsaturated fatty acids and omega fats (Gul *et al*., 2015). It contains 6 to 8 times less of the short chain fatty acids compared to milk from cows, goats, sheep, and buffalo (Gizachew & Tadesse, 2014). It is also reported to have a high content of unsaturated fatty acids (Karray *et al*., 2005; Konuspayeva *et al*., 2008; Ayadi *et al*., 2014).

Lactose is the major carbohydrate fraction in camel milk with range between 3.3-5.8% (Gebremichael *et al*., 2019). Lactose content is influenced by the nature of vegetation eaten by the camels to meet their physiological necessities of salts (Abbas *et al*., 2013). The mineral content in dromedary camel milk is between 0.60 to 1.0% and varies with feeding, breed and water intake (Konuspayeva *et al*., 2009). Camel milk is rich in; Na, K, Ca, P, Mg, Fe, Zn, Cu (Abbas *et al*., 2013). The mean values for zinc, manganese, magnesium, iron, sodium, potassium and calcium in dromedary camel milk (100g-1) are: 0.53, 0.05, 10.5, 0.29, 59, 156 and 114 mg respectively (Abbas *et al*., 2013).

Dromedary camel milk contains numerous vitamins such as; A, B-complex, C, D and E. It has high vitamin C levels (25-60 mg/l) approximately three times to cow's milk (Ramet, 2001; Farah & Fischer, 2004; Farah *et al*., 2007; Farah, 2017). Therefore, camel milk is paramount to pastoral communities in ASALs for its medicinal components and nutritive value especially as a source of Vitamin C because fresh fruits and vegetables are scarce. (Llorente *et al*., 2011; Jilo & Tegegne, 2016; Bedada & Lakew, 2018). Camel milk is reported to be hypoglycemic and has anti-cancer properties (Agrawal *et al*., 2003; Agrawal *et al*., 2005;Magjeed, 2005).

2.1.3.1 Factors influencing camel's milk composition

Composition of camel's milk depends on parity, quality of feed, breed, stage of lactation, geographical location, husbandry, and milk production potential of the camel (Iqbal *et al.*, 2001; Mal and Sena, 2007; Faye *et al.*, 2008; Al haj and Al Kanhal, 2010; Hammadi *et al.*, 2010; Aljumaah *et al*., 2011; Ayadi *et al*., 2014; Babiker and El-zubeir, 2014; Dowelmadina *et al*., 2014; El-zubeir, 2014; Shuiep *et al.*, 2014). High milk yielding camels have high milk protein but low milk fat content (Mal and Sena, 2007). Babiker & El-zubeir (2014) reported highly significant difference in lactose, fat, density, protein, solids not fat and total solids in milk of camels of 4th and 5th parity. On the contrary, Dowelmadina *et al*. (2014) study on influence of parity on milk composition of camel milk reported insignificant difference in milk fat, density and total solids. Camel milk fat, protein and lactose content are higher in early stage of lactation compared to late lactation (Zekele, 2007; Riyadh *et al*.,2012). It could be attributed to increase in milk water content with advancement of lactation (El-zubeir, 2014). This is in agreement with Elhassan *et al*., (2015) report that camel milk composition was significantly affected by the stage of lactation.

2.1.4 Effects of Supplementation on Milk yield and milk composition of dromedary camel

Dereje *et al*. (2015) reported a substantial increase in milk yield and milk fat in free ranging dromedary camels when they consumed supplementary concentrate feed prepared from a mixture of sorghum grain, wheat bran, noug seed cake and mineral vitamin premix in amounts of 0.5 and 0.75 kg per kg milk. However, there was no significant difference in ash, protein, solids not fat, specific gravity, pH and acidity of the milk (Dereje *et al*., 2015). Supplementation of camels with crude olive cake had no significant difference on milk yield, milk fat and milk protein (Faye *et al*., 2013). Onjoro *et al*. (2006) reported in increase in daily milk yield from 3.4 L/d to 4.3±0.3 L/d and 5.2 L/d in the dry and wet seasons, respectively for free ranging camels supplemented with mineral in Northern Kenya. Supplementing diets of dromedary lactating camels with palm oil decreased milk yield but did not affect the milk composition (total solids, solids not fat, milk fat, milk protein and lactose) (Soliman, 2009). Sagala *et al*. (2021) study reported increase in milk yield for browsing camels supplemented with 4 kg/day milled acacia tortilis pods and “chalbi salt”. Camels supplemented with Argane tree by-products (press oil cake and pulp) increased milk yield by 52.7% and improved all the physio-chemical parameters of milk except pH and salts (Ikram, 2019).

2.1.5 Camel feeding behavior

In pastoral practices, camels diets and feeding behavior varies extraordinarily (Dereje and Uden, 2005b). They graze and browse on a broad spectrum of forages that includes; halophytes, shrubs, grasses, trees, hard to thorny and bitter herbs, which grow naturally in ASALs (Iqbal &Khan, 2001;Dorges & Heucke, 2003; Dokata, 2014). Naturally, camels are more of browsers of shoots, young twigs, pods, fruits, leaves and flowers from trees than grazing on grasses because trees are higher in mineral content than grasses (Kuria, 2004; Laudadio *et al*., 2009; Abdelkreim *et al*., 2015). Field *et al*. (2005) study on the most browsed forages by camels in Marsabit County, reported to constitute of; dwarf shrubs (50%), trees (25%), herbs (14%) and grass (11%).

Camels tend browse more on trees and shrubs during the wet season than they graze on annual grasses and herbs (Chimsa *et al.*, 2013). However, it declines drastically during the dry season because most the species shed off their leaves (Field, 2005). Camels are less indiscriminative during the dry season because of forage scarcity and more selective during rainy season due to plenty forages (McLeod & Pople, 2008; Amin *et al*., 2011). Camels were reported to prefer shrubs, which constituted over 90% of their diets in the wet season (Kuria *et al*., 2012). Moreover, camels spend more than 80% browsing on dicotyledons (Kuria *et al.*, 2005). In the dry season, Alkali *et al.*(2017) reported that camels browse on green tips of trees.

Forage preference in camels depends on the amount, nutritive content and type of forage species available in the range (Shaheen, 2005). Although forage quality influences forage preference by camels, the total nutrient and dry matter intake depends on available time that camels are in the range (Kassilly, 2002). The camel forage preferences and nutritive value of consumed forages have been studied in different parts of the world. In Eastern Ethiopia, *Opuntia sp.*, *Acacia brevispica* and *Becium sp.* were reported as the most preferred species by both calves and mature camels (Chimsa *et al*., 2013). *Cadaba farinosa, Indigofera spinosa, Vernonia cinerascens, Maerua crassifolia* and *Acacia tortilis* dominated the diet of camels in Isiolo District, Kenya as well as in the Jijiga district, Eastern Ethiopia (Desalegn & Mohammed, 2012; Schwartz *et al*., 2012). *Euphorbia tirucalli* emerged as important drought forage for camels among the Borana in Northern Kenya (Kagunyu & Wanjohi, 2014). Sagala *et al.* (2020) study for browsed forages by lactating camels in peri-urban of Marsabit, in Kenya recorded *Acacia* species as the most browsed forage. The acacia spp., *Balanites aegyptiaca*, *Lycium europaeum*, and *Barleria* spp. were observed to be among the most browsed forage species by camels in the North Eastern Kenya (Kuria *et al.*, 2004)

2.1.6 Nutrient requirements of camels

In an animal's diet, protein and energy are the most limiting nutrients for both maintenance and production. Camels' feed intake in free-ranging conditions is not known. However, a study by Kuria (2004) in the North Eastern Kenya reported that Rendille and Gabbra consumed 1.67% of their live weight. The Metabolisable Energy requirements for maintenance of a camel animal was estimated to be 342 KJ/day/kg $W^{0.75}$ while the crude protein requirements for maintenance as 4.91 g/day/kg $W^{0.75}$ (Wardeh, 2004). The dry matter intake (kg/day) of a camel decreases with increase in lactation period and ranges between 9 to 11 kg per day (Nagpal & Patil, 2012).

Traditionally, camel farmers provide salt to their camels as they understand the importance of salt for their camels (Kuria, 2004). For instance, In Sudan, camels are provided with common salt (Sodium chloride) as mineral additive (Ishag *et al*., 2017). Mineral intake influences camel milk yield (Onjoro, 2004 ;Onjoro *et al*., 2006). That is phosphorus, copper, cobalt and calcium which are associated with energy metabolism , therefore, their deficiencies may reduce milk production (Onjoro, 2004). The main sources of minerals for animals exclusive to camels are both the drinking water and forages, however, forages may be deficient in minerals depending on geological origin and soil characteristics (Onjoro, 2004).

2.2 Cacti (*Cactaceae*)

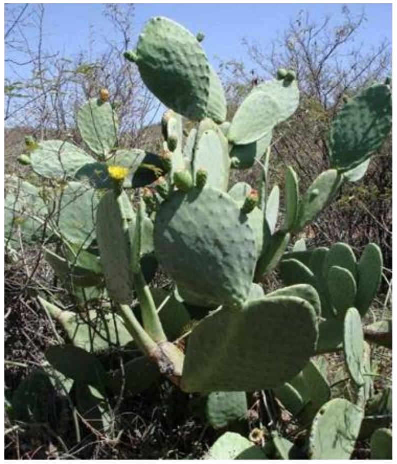
2.2.1 Overview of Cacti

Cacti belong to *Cactaceae* as the plant family and the order *Caryophyllales* (Kang'ara & Gitari, 2008). It is then classified into four other sub-families; *Cactoideae*, *Pereskioideae*, *Maihuenioideae* and *Opuntioideae* (Mauseth, 2006) with genus Opuntia as the largest (Segura *et al.*, 2007). Cacti have thick cuticles, asynchronous reproduction, shallow rooting systems, Craculacean Acid Metabolism, many water-storage tissues which adapts them to desert conditions (Nobel, 2002; Khalafalla *et al.*, 2007; Kang'ara & Gitari, 2008; Barigabre *et al.*, 2016). They are therefore, xerophytic and perennial plants that survives in hot-dry geographical locations. They slowly grow with partial reproductive capacity, limited seed production, germination and flowering (Khalafalla *et al.*, 2007). They are often hermaphrodites with dichogamy and herkogamy (Webb, & Lloyd, 2011) whose selfing is controlled by self-incompatibity and inbreeding depression (Ramawat, 2010). Cacti flowers are either epigynous (ovaries are inferior) or with superior flowers. They are entomophilous (pollinated by birds, insects or bats) (Böhm, 2008). The seed and pollen morphology of Cacti have been documented by (Kurtz, 2009;Cota-Sánchez & Bomfim-Patrício, 2010). Most Cacti are dimorphic, that is, they are of different morphology and anatomy at different stages of growth (Mauseth, 2006). They have different forms of growth; pendent, climbers, globular, clustering, columnar and leaf-like. They can be long, leafless, huge, spiny, spineless, fresh stems of different sizes and shapes. The flower varies from colorful, large, and solitary to several segments. The stems can be flat, tubercle, spherical, spineless, terete, cylindrical or ribbed. Their areoles are located at the axils of either leaves or stems (Anderson, 2001). Cacti have different roots which include; shallow root for water storage, for example *Lophophora* and *Ariocarpus* large taproots, short lateral roots especially globuse Cacti (Anderson, 2001; Nobel, 2002).

Cacti fruits of different sizes, color, morphology and located at various parts of the plant. For instance, *Opuntia stricta* fruits have glochids while *Euphorbia abyssinicca* fruits do not have glochids. *Cereus peruvianus* fruit is formed at the edges of its branches, *Opuntia monacantha* on cladodes' edges while *Thrixanthocereus blossfeldiorum* forms on the stems. In ripe fruits *Opuntia stricta* is purple, *Opuntia exaltata* light green, *Thrixanthocereus blossfeldiorum* red, *Cereuper uvianus* violet-red, while *Opuntia ficus-indica* is orange in color (Omweri *et al.*, 2016). In Kenya, Cacti are found in the ASALS. They have distinct morphologies in shapes, growth forms, stems, fruit color, and cladodes, spiny or spineless. These are as follows; *Opuntiaficus-indica* (Plate 2.1) in Nakuru and Laikipia countiesis arborescent with elliptic cladodes, orange corolla and an orange fruit, *Opuntia exaltata* in Nakuru, Laikipia and Machakos counties, is shrubby with cylindrical cladodes, green fruits and pink corolla (Muchane *et al*., 2017). *Opuntia monacantha* in Baringo and Makueni counties, is arborescent with oval to elliptic cladodes, purple fruits and yellow corolla with purple strips, *Opuntia stricta* in Makueni, Machakos and Laikipia Counties, have purple fruits, bright yellow corolla and oval cladodes, *Thrixanthocereus blossfeldiorum* in Machakos county, is columnar with, red and single-seeded fruits (Shackleton *et al*., 2017). *Cereus peruvianus* in Nakuru and Baringo counties has brown spines, violet-red fruits, ribbed branches and steps with arborescent form of growth, *Euphorbia ingens* (Plate 2.1) has purple fruits that are oval in shape, drooped round arborescent is found in Nakuru and Baringo counties while, *Euphorbia abyssinica* in Baringo, Laikipia, Machakos and Makueni Counties has purple fruits, short balck spines, arborescent and globular (Omweri *et al.*, 2016).

In exception of the genera *Thrixanthocereus* and *Cereus* which do not have cladodes, all species of genera *Opuntia* have cladodes (Peña-Valdivia *et al.*, 2008). The cladodes of *Opuntia* have different shapes that are important in distinguishing them, for instance, *Opuntia ficus-indica* and *Opuntia monacatha* are elliptic, is *Opuntia stricta* ovate, while *Opuntia exaltata* is cylindrical (Peña-Valdivia *et al.,* 2008; Chalak *et al.*, 2012). In Kenya, cacti are used as ornaments, for example; *Euphobia abyssinica, Thrixanthocereus blossfeldiorum* and *Cereus peruvianus* while *Opuntia exaltata, Opuntia ficus-indica* and *Opuntia monacantha* are used as fence or as a border in farms. The other species *Opuntia stricta*, *Cereus peruvianus, Euphorbia ingens,* and *Euphorbia abyssinica* spread intermittently in rangelands (Omweri *et al.*, 2016).

Opuntia exaltata



Opuntiaficus-indica

Opuntia stricta

Opuntia moncantha

Thrixanthocereus blossfeldiorum

Cereus peruvianus

Euphorbia ingens

Euphorbia abyssinica

Plate 2.1: Photos of various types of cactus found in Kenya

2.2.1.1 Description of *Opuntia stricta*

Opuntia stricta is an erect plant of 50-100cm in height and sometimes can be 2m tall, categorized as a perennial shrub. It is succulent with several flat cladodes on branched stems. The ladodes are of obovate (round shape), color green, of width (7-20cm), length (10-35 cm), and thickness (10-20cm). The cladodes are glabrous, with areoles and glochids with spines of 2-4cm in length. The leaves are shed from developing cladodes as 4.5-6 mm conical and cylindrical shaped tiny structures. The flowers are approximately 7cm long and 6-8 cm wide, bright yellow in color with pinkish-red color on petaloids, formed on the margin of the cladodes. The flowers have many stamens and petaloids. Immature fruit is color green while mature fruit is red to purple (Plate 2.2).

It has succulent berries (2.5-4 cm wide and 4-8cm long), obovoid, that is, egg-shaped, with tuffs of glochids on the surface and slightly depressed tips. Its fruit has sour taste, red-purple pulp with numerous seeds at the centre. The seeds are sub-globular (round in shape), light brown to yellow in color, 4-5mm long and 4-4.5mm wide. It reproduces by both sexual and vegetative forms. It has Crassulacean Acid Metabolism (CAM) and nocturnal stomatal opening that conserves water contributing to its survival and adaptation in very hot dry environments (Nobel and Bobich, 2002; ICARDA, 2017).

Plate 2.2: Photo showing invasive *Opuntia stricta* in Laikipia County
Source: Ikanya, unpublished data

2.2.1.2 Origin and distribution of *Opuntia stricta*

Opuntia stricta is also known as Haw or erect prickly pear. It was originally from Atlantic coast of Florida, Gulf in Central America, Caribbean region, Virginia, North and South Carolina. It grows naturally in Middle East, Spain, Australia, South and East of Asia, North, South and East of Africa. It is regarded as invasive species in Australia especially in New South Wales, North-eastern and South-eastern Queensland (Le Houerou, 2002). In Africa, it has infested the dry savanna in South Africa, Namibia, Ethiopia, Somalia, Uganda, Kenya, and Tanzania. In Kenya, it is regarded as invasive species deteriorating rangelands in ASALs (Shackleton *et al.*,, 2017). It was introduced in East Africa in 1950s. In Kenya, *Opuntia stricta* is commonly found in Laikipia North, and Tsavo East National Park in Voi where it is thought to have been introduced during the construction of the railways in the 1900s (Githae, 2018).

2.2.2 Production, utilization and economic importance of *Opuntia*

Opuntia is the largest genera in Cactaceae family (FAO, 2013). It is utilized as a fence, border, fodder, vegetable, fruit, or medicine depending on vegetative vigor, fiber, sugar and protein content with a long history of human use globally (Ervin, 2012; Chiteva & Wairagu, 2013). Cacti is commercialized for various purposes in some countries such as Israel, South Africa, Italy, Japan, Chile and Mexico with Japan being the world's major consumer of cacti products (Khalafalla *et al*., 2007; Caloggero & Parera, 2015). For example, in Mexico, Cacti is grown for edible pads and fruits, cultural, industrial and commercial use as medicine (Anderson, 2001; Segura *et al*., 2007). In Ethiopia *Opuntia* combats desertification through water and soil conservation as well as source of income (FAO, 2002; Ervin, 2012; Belay *et al.*, 2015). Its shallow roots are reported to stabilize the soil (Mellink and Riojas-Lopez, 2002). It has positive impact on natural ecosystems as mammals, insects and birds feed on their cladodes and fruits.

It has also been utilized in cochineal production for textile dye (Najad, 2015). Its fruits have high flavors and nutritive value especially Vitamin C and therefore used in manufacturing juices, alcoholic drinks, jams and natural liquid sweeteners (Piga, 2004; Chiteva & Wairagu, 2013; Yeddes *et al.*, 2013). However, there is limited commercialization of processing Cacti fruits for lack of know-how (Moßhammer *et al.*,2006). Proper management of Cacti can increase its productivity to large quantities of forage for livestock feed as it provides the much needed energy, water and vitamins especially during the dry season (Le Houérou, 2002; Kang'ara & Gitari, 2008). However, protein supplementation in cactus diet is paramount and the *Opuntia* cladodes have insufficient crude protein (Mashope, 2007). The cacti's spines have been used to make fish hooks, religious purposes, and biogas production with cow dung (Anderson, 2001; Gebrekidan *et al.* 2014).

Algeria, Argentina, Brazil, Chile, Mediterranean region, Mexico and South Africa have established commercial plantation for Cacti pear (Anderson, 2001). Mexico have more than 53,876 ha commercial plantations which yield more than 428,763 tons of fresh fruit which is approximately 7.96 ton/ha (Vazquez *et al.*, 2017). Le Houérou (2002) study reported 246 tons/ha of fresh cladodes in fertilized irrigated commercial plantations. Arid areas can yield an average of 20-60 metric tons ha of fresh cacti fruit on annual rainfall of 200-400mm and without fertilization (FAO, 2002). In Ethiopia, a plantation of 30,520 ha produced 128, 660 tons of cacti fruit, that is approximately, 4.22 ton/ha (Shackleton *et al.*, 2017). Mutwa *et al.*(2015) study on productivity of *Opuntia* species in Kenya reported that *Opuntia monacantha* produced 6.43kg/m^2 while *Opuntia ficus-indica* produced 11.38kg/m^2. In Kenya, utilization of cactus is constrained by dangerous spines, cultural factors with regard to it as invasive and poisonous (Githae & Nyangito, 2010). Cacti contain antioxidant bio compounds such as phenolic and betalain compounds that are preventive against degenerative diseases, enhance cell growth and prevents inflammation in humans through the positive effect on redox-regulated pathways (Sumaya-Martínez *et al*., 2011; Yeddes *et al.*, 2013).

However, Cacti is regarded invasive species in the ASALs parts of Kenya as it restricts human access, displaces people, native species and cause injury to both livestock and wild animals by forming dense shrubs (Kang'ara & Gitari, 2008). An increase in *O. stricta* density decreases plant diversity (Brolin, 2004). Larsson (2004) report from pastoralists states that consumption *O. stricta* by their livestock leads to death. In Baringo County, Kenya, the local communities believe that Cacti degrades lands leading to desertification (Kang'ara & Gitari, 2008). Dissemination of information on utilization and benefits of Cacti in other countries could minimize the cultural factors that limit utilization of Cacti in Kenya.

2.2.3 The Nutritive value of *Opuntia*

According to Grünwaldt *et al*. (2015) study on nutritive value of different *Opuntia* species fed on livestock, *Opuntia* cladodes were reported to constitute of 11.3% dry matter (DM), 2-6% crude protein (CP), 8-15% crude fiber (CF), 0.11-0.47% phosphorus on dry matter basis. It has 28.5% neutral detergent fiber (NDF), 20.1% acid detergent fiber (ADF), 65% total digestible nutrients, 55.4% soluble carbohydrates (Dubeux, 2010). It has high moisture, ash and calcium content; 80-90% moisture, 15-25% ash and average of 93mg/100g calcium content in dry matter basis (Kawas, 2011; Mostafa, 2015). The high moisture content in Cacti reduces the animal's voluntary water intake therefore meeting the animal's water requirements (Kawas, 2011; Violeta *et al*., 2017). Cactus cladodes have high soluble carbohydrates and rich in vitamin A (Mostafa, 2015). However, protein supplementation in Cacti rations is paramount as it has low crude protein content (Brandão & Costa, 2012).

2.2.4 Factors affecting the nutritive value of *Opuntia*

The nutritive value of *Opuntia* depends on; species, age, variety, fertilization, harvesting management, part of plant and season (Mostafa, 2015; Lopes, 2018). Velázquez *et al*., (2010) study reported spineless *Opuntia* cladodes contain 28% starch, 38.8% neutral detergent fiber (NDF), and 48.9% acid detergent lignin (ADL) in dry matter basis. Young cladodes have higher crude protein, ash and moisture content than mature cladodes but lower in starch and crude fiber content (Syomiti *et al*., 2014). Bimolecular compounds concentration in cladodes are high during the dry season with low water content than in wet season (Mostafa, 2015).Velázquez *et al*., (2010) reported that total carbohydrates, neutral detergent fiber (NDF) and organic matter increases with age while crude protein decreases but dry matter and ash content were not significantly affected. The soluble fiber contents decreases with maturity **(**Ventura-aguilar *et al*., 2017). Salem *et al*., (2009) study on spiny and spineless cactus reported that variety of *Opuntia* influences the nutritive composition, bacterial nitrogen production, *in vitro* digestibility and volatile fatty acids.

2.2.5 Post-harvest quality of *Opuntia*

Opuntia can only be stored at a maximum of two weeks to maintain feed value and chemical composition (Dubeux, 2010). However, Rodríguez Verástegui *et al*., (2015) reported that *Opuntia* cladodes had microscopic hanges when stored at 4°C, 12°C and 26°C. After 7 days, the Opuntia cladodes stored at 26°C had lost water from the breaking up of the cellular structure leading to a firm fibrous texture. Prolonged post-harvest life influences the physiological changes and chemical composition of *Opuntia* cladodes which in turn affects its functional (Ventura-aguilar *et al*., 2017).

2.2.6 In vitro digestibility of *Opuntia*

Mostafa, (2015) study on *Opuntia* degradability reported 65% *in vitro* dry matter digestibility. It has relatively high digestibility because of the high content of soluble carbohydrates such as pectin which rapidly ferments in the rumen (Mehari *et al*., 2016; Araujo *et al*., 2017). It therefore increases degradability rates of crude protein, dry matter and neutral detergent fiber as reported by Menezes *et al*., (2010) and Medeiros *et al*., (2013) improving the nutritive value of poor quality forages (Felipe *et al*., 2016). Menezes *et al*., (2010) reported that increase in prickly pear in the diet increased the digestibility of neutral detergent fiber. *In vitro* digestibility, potential solubility and dry matter digestibility rate decreases with increase in age of the *Opuntia* (Velázquez *et al.*, 2010). Utilization of Opuntia as forage improves the animal performance by increasing the digestibility of nutrients (Kawas, 2011; Violeta *et al*., 2017).

2.2.7 Effects of inclusion of *Opuntia* in livestock's diet on animal performance

Opuntia is a common feed for livestock in the ASALs regions of the world as it's survives in dry climatic environments and still remains productive and nutritious (Agropecu, 2018). Previous documented studies, have recommended only partial replacement of conventional feed resources with prickly pear as it causes diarrhea and has insufficient dry matter, crude protein content and other nutrients (Combrinck, 2014). Medeiros *et al*., (2013) study reported reduced weight gain in livestock whose diets were total substitution of corn by prickly pear. *Opuntia* diets should therefore be supplemented with fiber or source of crude protein such as concentrate or urea (Dubeux, 2010). In spiny *Opuntia,* spines have to be removed before feeding livestock. The spines can be removed through burning in a bonfire (Kang'ara and Gitari, 2010).

Prickly pear can be utilized both as a feed supplement an a source of water(Salem *et al*., 2009; Salem, 2010;Kawas, 2011; Taddesse *et al*., 2014). Water intake by livestock decreases with increase in prickly pear intake (Costa *et al*., 2009). Voluntary dry matter and water intake decreases with increase in amount of *Opuntia* in sheep's diet, therefore, the high water content in prickly pear can sustain livestock without water up to 60days during water scarcity (Violeta *et al*., 2017). Additionally, Violeta *et al*., (2017) study reported that higher daily water intake in sheep fed 50% prickly pear diet in comparison to the sheep fed 70% prickly pear. Salem, (2010) study shown a significant effect on growth in Barbarine lambs fed *Atriplex nummularia* diets supplemented with cactus. However, supplementation of cactus above 60% of the diet decreases the dry matter intake of animals (Llorente *et al*., (2011);Medeiros *et al*.,(2013). Jilo & Tegegne (2016) reported a significant increase in live weight gain and reduced water intake in sheep fed pasture hay substituted with cactus at an optimal level of 60%. A study by Kawas, (2011) reported higher weight gain in livestock fed diets substituted with cactus at 30% to 50% level. Additionally, no negative effect on animal performance was noted even on restricted water intake in the entire experimental study. Lambs fed diets substituted with spineless prickly pear of less than 45% dry matter, had higher growth performance due to increased microbial efficiency and nutrient utilization (Cardoso *et al*., 2018). Diet composition influence voluntary water intake by animals as animals acquire water either from food especially moist and succulent foods or by drinking water (Garcia *et al*., 2010; Vilela *et al*., 2010).

Ferreira (2017) study that evaluated different protein supplements in spineless cactus' based diets reported insignificant difference on weight gain and feed conversion in heifers supplemented with whole cotton seed, cotton seed meal and soybean meal. Lopes *et al*. (2009) study reported a better daily weight gain, feed conversion efficiency and dressed carcass weight in highland sheep supplemented with iso-nitrogenous oil seed cakes in tef straw and cactus based diets compared to the non-supplemented. Supplementing dried cactus cladodes with *Acacia senegal* branches on male Tigray highland sheep had a significant increase in the crude protein intake, average daily weigh gain and feed conversion efficiency (FCE) with increased proportion of *Acacia senegal* branches in the foliage mixture (Mengistu *et al*., 2016). Ferraz *et al*., (n.d.) reported that spineless cactus with soybean meal and cotton seed meal based diets for lambs reported high digestibility, improved physiochemical composition and carcass characteristics.

CHAPTER 3

3 CHEMICAL COMPOSITION AND DIGESTIBILITY OF PREFERRED FORAGE SPECIES BY LACTATING SOMALI CAMELS IN KENYA

3.1 Abstract

In Kenya, camels are mainly kept by Somali people in the North-Eastern parts of Kenya. Due to recurrent prolonged drought, camels have recently gained importance in Laikipia that did not hitherto keep camels. In addition, camels are both grazers and browsers of a broad spectrum of forages whose nutrient composition is not well documented. Therefore, there is a need to determine the chemical composition to exploit the potential of the available preferred forages in different seasons to improve camel production. The objective of this study was to identify the most preferred forages by lactating Somali camels in Laikipia, and determine their chemical compositions. Lactating Somali camels and their calves were observed during the wet and dry seasons from August to November 2019 while browsing and grazing in the range. The forage species were ranked based on the bite counts. The most browsed forages identified through observation were sampled, identified by the local and scientific names, and analysed for proximate composition, detergent fiber fractions, and *in vitro* dry matter digestibility. The most browsed forage species were; *Acacia nubica* (22.6%), *Acacia seyal* (47.3%), *Cucumis aculeatus* (7.2%), *Euclea divinorum* (11.1%), *Hibiscus parrifolia* (11.9%) during the wet season, and *Barleria acanthoides* (22.9%), *Balanites aegyptiaca* (15.5%), *Cynodon dactycon* (11.7%), *Lycium europium* (32%), *Pollichia campestris* (17.8%) during the dry season. Shrubs constituted 60%, trees 30%, and grasses 10% of the most preferred forage species. The preferred browsed and grazed species had a range of; (7.1±0.4 to 25.7±1.2%) crude protein on a dry matter basis, (29.1±2.7 to 74.0±7%) neutral detergent fiber concentrations in dry matter basis, and (43.4±0.2 to 81.6±0.3 %) *in vitro* dry matter digestibility. The results of the study show camels feed on

different types of forage depending on season and their forage nutritive value influenced the selection.

Key Words: bite count; Somali dromedary; forage species; feeding behavior

3.2 Introduction

In the recent past, camels have increasingly gained importance among counties that did not hitherto keep them due to recurrent prolonged drought in Arid and Semi-arid lands as a climate adaptation strategy as well as increased demand for camel milk due to the associated health benefits (Kagunyu & Wanjohi, 2014; Opiyo *et al.*, 2015; (Watson *et al.*, 2016). In pastoral practices, camels diets and feeding behavior varies extraordinarily (Dereje and Uden, 2005b). They graze and browse on a broad spectrum of forages that includes; halophytes, shrubs, grasses, trees, hard to thorny and bitter herbs, which grow naturally in ASALs (Iqbal &Khan, 2001;Dorges & Heucke, 2003; Dokata, 2014). Naturally, camels prefer browsing on shoots, young twigs, pods, fruits, leaves and flowers from trees than grazing on grasses because trees are higher in mineral content than grasses (Kuria, 2004; Laudadio *et al.*, 2009; Abdelkreim *et al.*, 2015). Grazing refers to feeding on forage that grows near the ground while browsing is feeding on high-growing forage (Gordon, 2003). Camel's forage preference varies with forage nutritive value, season, type, and amount of forage available (Shaheen, 2005; Temesgen & Mohammed, 2012; Medila *et al.*, 2015, Salamula *et al.*, 2017). Previous studies on forage preferred by camels in Kenya have concentrated on ancient camel keeping counties, that is, Baringo, Isiolo, Marsabit, and Turkana (Kassilly, 2002, Kuria *et al.*, 2005, Schwartz *et al.*, 2012; Lengarite *et al.*, 2012; Kagunyu & Wanjohi, 2014; Sagala *et al.*, 2020). Despite the potential and increasing number of camels in the emerging camel-keeping counties to reduce the vulnerability of pastoral communities to climate variability, there is limited literature on the quality of preferred browsed forage by camels. This study was conducted to identify and determine the chemical composition and *in vitro* dry matter digestibility of the most browsed forages by lactating Somali camels in Laikipia County, Kenya with the aim to effectively managing the grazing lands to maximize camel production.

3.3 Materials and Methods

3.3.1 Description of the Study Site

The study site was at Doldol in Laikipia County, Kenya (Plate 3.1). The area is semi-arid and deemed too dry for cultivation comprising a relatively intact and natural habitat, which is mainly a wildlife habitat (Jong, 2014). It lies approximately between altitude 1166 to 2122m above sea level, and geographical coordinates of 0.3932^0 N and 37.1632^0 E, with an annual average rainfall of 554mm (GOK &UNDP, 2013). It receives a bi-modal rainfall pattern with peaks in April and November. The area is a hot steppe climate with an annual temperature ranging from a minimum of 24.6^0 C to a maximum of 33.3^0 C, with the period between July and September being very hot. It is inhabited by Maasai pastoral communities who rely on natural resources and livestock for a livelihood, source of income, and accumulation of wealth (Mahmoud, 2011). The population is low and they share water resources (Government of Kenya, 2013). The site was selected due to the increasing number of camels replacing cattle and the existence of a camel farmer group with a herd of more than 300 camels (KNBS, 2019).

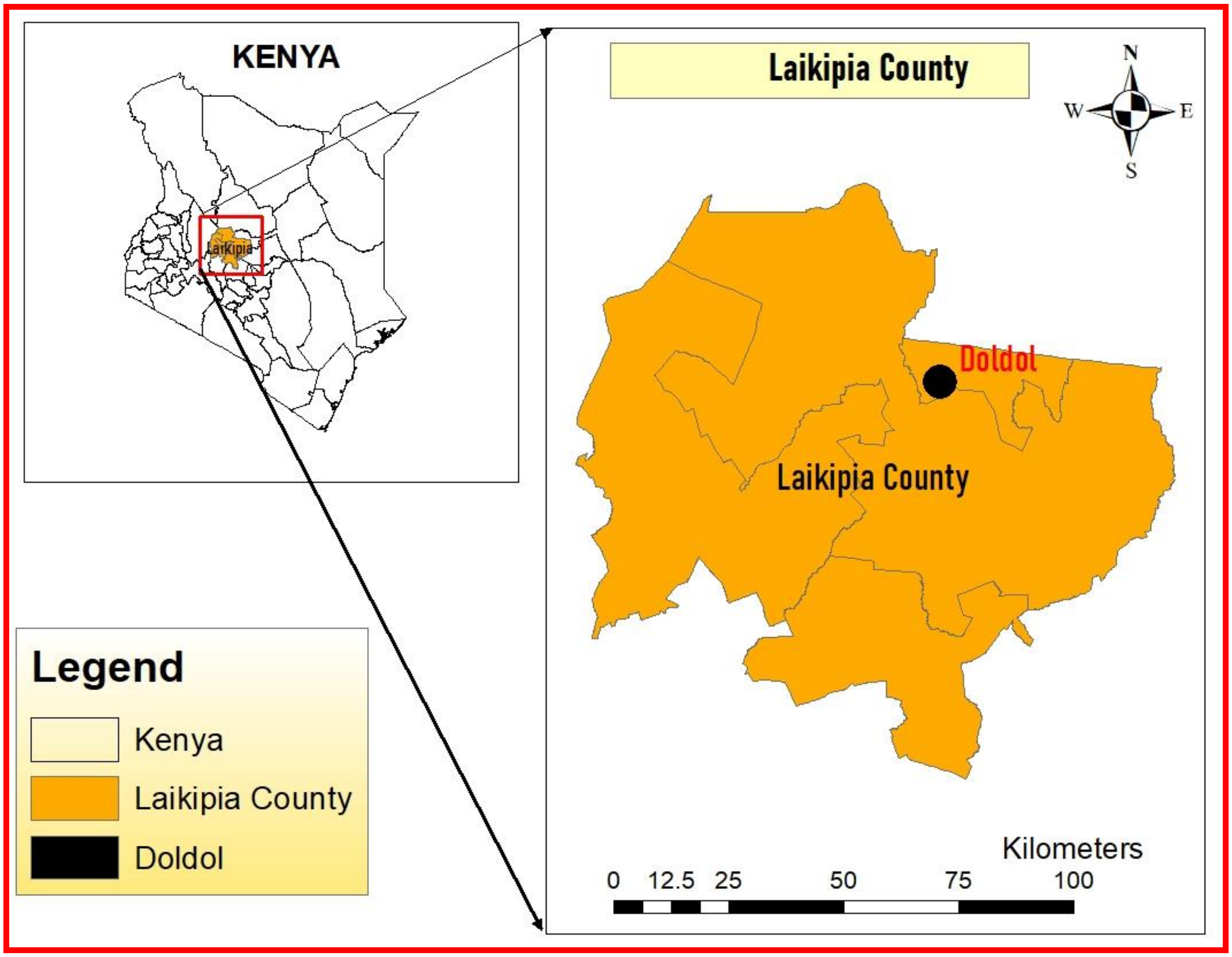


Plate 3.1: Map of the study area: Doldol in Laikipia County, Kenya

3.3.2 Identification of preferred forage species

Eight Somali lactating camels were selected randomly from different herds through visual assessment for healthy camels. That is, gait steady, sleek coat, alertness, chewing cud, normal respiration, urine, and feces. The lactating camels were of parity one to three, in the early stage of lactation and two to four months post-calving period. The experimental camels were ear-tagged with a Button electronic ear tag, Raybaca brand; model RBC-ET01 LF for identification before the start of the experiment. The lactating camels were observed for forage identification during the dry season in the months of August and September and during the wet season in the months of October and November. The visual observations were done from 1000h to 1800h when the camels were browsing and grazing in the rangelands (Plate 3.2). Each camel was observed while grazing in the communal land for 60 minutes daily for 5 days a week by the same researcher and a trained local herder who was able to identify the different species. The bites of each forage species by every camel were counted and recorded from the time a camel took a bite to raising its head for chewing. Summation was done to determine the total number of bites made on each forage species by different camels.

Plate 3.2: Photo of the researcher observing camels in the range during forage identification

3.3.3 Sampling Procedure

The forage species were ranked based on the highest percentage of total bite counts throughout the study. The most preferred forages were ranked in both wet and dry seasons and were sampled for laboratory analysis. Sampling involved picking the forage species consumed by the camels during the field observation. This was accompanied by the identification of the local name by the pastoral community. Known weight of the browsed forage species were packaged and labeled in khaki bags. The bags were sealed using a stapler and transported 270km to the University of Nairobi, Kabete Campus, Animal Nutrition Laboratory, ISO 9001: 2015 certified, of the University of Nairobi. Fresh forage samples were also taken to a botanist in the University of

Nairobi, Department of Land Resources Management and Agricultural Technology (LARMAT), for the identification of scientific names.

3.3.4 Laboratory Analysis

3.3.4.1 Determination of Moisture Content

The samples were dried at both 60^0C and 105^0C overnight to determine the dry matter content. A known amount of sample was oven-dried at 60^0C for 72 hours, weighed and ground using Wiley mill with 1mm sieve WRB80C/2Q model.

3.3.4.2 Proximate Analysis

Proximate composition was determined using standard procedures (AOAC, 2005). Crude protein was determined using Macro-kjedahl method, Ash was determined by burning known amounts of the dried, ground samples in a muffle furnace at 550^0C for 2hours followed by cooling and weighing. Ether Extract was done using a soxhlet extractor with petroleum ether as the extract.

3.3.4.3 Mineral, fiber content and digestibility determination

Two grams of samples were dry ashed then digested with 20ml of 20% hydrochloric acid, filtered through Whatman no. 1 filter paper, and made up to 50 ml with distilled water. The solution was assayed for both calcium and phosphorus concentration respectively. Samples were assayed for calcium through the atomic absorption spectrophotometric method (Bellanger & Lamand, 1975). A wavelength was set to 422.7nm in a bulk scientific model bulk 210 (Made in the U.S.A) atomic absorption spectrophotometer with an air-acetylene flame. Calcium carbonate was used to prepare standards (0 – 10ppm with a gradient of 2) for the calibration curve. Phosphorous was analyzed through calorimetric methods (Kitson & Mellon, 1944) (Plate 3.3). 2ml of this solution was transferred into a 50ml volumetric flask and 15ml of phosphorous yellow color developer (mixture of ammonium molybdate and sodium vanadate) was added and the contents topped up to the mark with distilled water. A 1000ppm commercial standard was purchased from Pyrex east Africa Nairobi and was used to prepare phosphorous standards of the range 0-10ppm. A spectrophotometer (HITACHI U-2900, Made in Japan) set at a wavelength of 400nm was used to determine the yellow color intensity.

The fiber fractions; neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined according to Van Soest *et al.* (1991). One gram sample was refluxed for one hour in 100mls of NDS, filtered through sintered glass crucible, and dried at 105^0c overnight and the resultant NDF residue was weighed. The NDF residue was refluxed with 100ml ADS, filtered, dried at 105^oc and ADF content weighed. Cellulose content was digested out using 72% H_2SO_4 for 3hours. The residue after acid digestion was weighed and burned out at 550^oc to determine lignin content. *In vitro* dry matter digestibility of the forage species was determined by the two-stage Tilley & Terry (1963) method. One part of rumen fluid from a fistulated bull was mixed with four parts of McDougall's artificial saliva, flashed with CO_2, and stirred thoroughly with 1 gram of sample. The samples were incubated in the laboratory at 39 ºC for a total of 96 hours (48 hours fermentation followed by 48hrs digestion of protein using enzyme pepsin in acidic medium), drained on crucibles, and dried in an oven at 60 ºC. Artificial saliva was prepared according to McDougall (1947).

Plate 3.3: Researcher analyzing for phosphorus using the calorimetric method at the University of Nairobi

3.3.5 Data Analysis

Data was entered in Microsoft Office Excel 2010 datasheet. Mean of the laboratory data, frequencies and percentages for bite counts were then computed using the Statistical Program for Social Sciences Version 25 (SPSS).

3.4 Results

3.4.1 Browsed and grazed forages by camels

The browsed species by camels are presented in Table 3.1.

Table 3:1: The forages browsed and grazed by Somali lactating camels in the Laikipia rangeland

Wet season			Dry Season		
Botanical Name	**Local Name**	**Category**	**Scientific Name**	**Local Name**	**Category**
Acacia brevispica	ol-girgiri	Tree	*Maerua johannis*	ol-amaloki	Tree
Acacia mellifera	e-melelek	Tree	*Balanites aegyptiaca*	Lokwai	Tree
Acacia nubica	Jakwai	Tree	*Commiphora africana*	o-silalei	Tree
Acacia senegal	ol-derkesi	Tree	*Euphorbia tirucalli*	ol-oileoibor	Tree
Acacia seyal	Oltepesi	Tree	*Grewia bicolor*	o-siteti	Tree
Acacia tortilis	ol-gorete	Tree	*Rhus natalensis*	ol-misikioi	Tree
Cordia quercifolia	ol-dorko	Tree	*Ozoroa insignis*	o-lokunonoi	Tree
Rhus natalensis	ol-misikioi	Tree	*Lycium europaeum*	Ngoki	Shrub
Euclea schimperi	Olkinyei	Tree	*Indigofera lupatana*	e-min	Shrub
Cucumis aculeatus	Sengeti	Shrub	*Datura stramonium*	en-abooi	Shrub
Duosperma eremophilum	ol-tameyioi	shrub	*Opuntia stricta*	Matunda	Shrub
Euclea divinorum	o-sojo	Shrub	*Pollichia campestris*	Nkaekuch	Shrub
Hibiscus parrifolia	Nkarani	Shrub	*Barleria acanthoides*	Suchei	Shrub
Indigofera lupatana	e-min	Shrub	*Cynodon dactylon*	Nkigit	Grass
Justicia diclipteroides	e-sonkoyo	shrub			
Lantana salvifolia	magirigiriana	Shrub			
Premna oligotricha	ol-tai	Shrub			
Solanum incanum	en-tulelei	Shrub			
Dactyloteniun bogdanii	ol-murua	Grass			
Themeda triandra	ol-peresi	Grass			

3.4.2 Most preferred forage species

The most preferred forage species by camels in the study area are presented in Table 3. 2. The most preferred browsed and grazed forage species were; *Acacia seyal* (47.3%), *Acacia nubica* (22.6%), *Hibiscus parrifolia* (11.9%), *Euclea divinorum* (11.1%), *Cucumis aculeatus* (7.2%)

during wet season and *Lycium europium* (32%), *Barleria acanthoides* (22.9%), *Pollichia campestris* (17.8%), *Balanites aegyptiaca* (15.5%), *Cynodon dactycon* (11.7%), in the dry season. Shrubs constituted 60%, trees 30%, and grass 10% of the most preferred forage species.

Table 3:2: Most preferred forage species by Somali lactating camels in Laikipia

Season	Local name	Botanical name	Category	Bite counts	% of total	LSmeans±SE
Dry	Ngoki	*Lycium europaeum*	Shrub	208	32	52.0±2.9
	Suchei	*Barleria acanthoides*	Shrub	149	22.9	37.2 ± 0.5
	Nkaekuch	*Pollichia campestris*	Shrub	116	17.8	29.0±0.7
	Lokwai	*Balanites aegyptiaca*	Tree	101	15.5	25.2±0.8
	Nkigit	*Cynodon dactylon*	Grass	76	11.7	19±1.3
	Total			650	100	
Wet	Oltepesi	*Acacia seyal*	Tree	414	47.3	103.5±3.6
	Jakwai	*Acacia nubica*	Tree	198	22.6	49.5±2.5
	Nkarani	*Hibiscus parrifolia*	Shrub	104	11.9	26.0±1.8
	Olkinyei	*Euclea divinorum*	Shrub	97	11.1	24.2±0.5
	Sengeti	*Cucumis aculeatus*	Shrub	63	7.2	15.8±0.9
	Total			876	100	

3.4.3 Chemical composition of the most preferred forage species

Among the most browsed species, dry matter (DM) ranged from 20.5±0.2% in *Lycium europium* to 72.2±0.1% in *Barleria acanthoides.* The crude protein (CP) content ranged from 7.4±0.8% in *Balanites aegyptiaca* pods to 25.7±1.2% in *Lycium europeum.* Ash content was lowest in *Balanites aegyptiaca* pods (5.9±0.1 %) while the highest was in *Lycium europaeum* (22.9±0.5%). The Ether extract concentrations ranged from 0.9±0.2 to 3.3±0.8%, the highest being for *Balanites aegyptiaca* pods and the lowest for *Barleria acanthoides*. *Lycium europaeum* and *Barleria acanthoides* had the highest calcium concentration (2.0±0.0% and 3.4±0.0%), respectively. In phosphorus concentrations, *Balanites aegyptiaca* leaves had the lowest (0.1±0.0%) (Table 3.3).

Table 3:3: Chemical composition (% DM) of the most preferred forage species by lactating camels

Scientific Name	% Mean±SD					
	DM	CP	Ash	EE	Ca	P
Acacia seyal	39.0±0.2	17.9±1.3	8.2±0.1	2.0±0.1	1.7±0.1	0.3±0.0
Balanites aegyptiaca leaves	51.5±0.2	12.5±2.2	16.3±0.5	2.1±0.1	1.4±0.0	0.1±0.0
Balanites aegyptiaca pods	41.5±0.5	7.1±0.4	5.9±0.1	3.3±0.8	0.7±0.0	0.3±0.0
Barleria acanthoides	72.2±0.1	7.4±0.8	19.3±1.2	0.9±0.2	3.4±0.0	0.2±0.0
Cynodon dactylon	54.9±0.2	10.4±0.8	11.8±2.2	2.5±0.7	0.9±0.0	0.3±0.0
Euclea divinorum	51.0±0.2	7.6±0.4	6.6±0.2	1.5±0.9	1.6±0.3	0.2±0.0
Lycium europeum	20.5±0.2	25.7±1.2	22.9±0.5	2.2±0.2	2.0±0.0	0.3±0.0
Pollichia campestris	53.1±0.1	8.2±0.4	9.3±1.0	1.5±0.2	1.3±0.0	0.2±0.0

DM-Dry matter, CP-Crude protein, EE- Ether Extract, Ca-Calcium, P-Phosphorus

3.4.4 Fibre fractions and *in vitro* dry matter digestibility

In vitro dry matter digestibility (IVDMD) ranged from 43.4±0.2% in *Pollichia campestris* to 81.6±0.3% in *Lycium europeum.* The highest neutral detergent fiber (NDF) content was recorded for *Cynodon dactylon* (74.0±7%) while *Acacia seyal* (29.1±2.7%) had the lowest. The highest acid detergent fiber (ADF) was recorded for *Pollichia campestris* (47.8±2.8%) while the lowest value was for *Acacia seyal* (15.2±0.9%). There were no consistent patterns between fiber fractions and *in vitro* dry matter digestibility on the most browsed and grazed forage by the camels (Table 3.4).

Table 3:4: Fiber fractions (%DM) and in vitro dry matter digestibility (%) of the most preferred forage species by lactating Somali camels

Scientific Name	% Mean±SD				
	IVDMD	NDF	ADF	Hemicellulose	ADL
Acacia seyal	64.2±1.3	29.1±2.7	15.2±0.9	13.9±1.7	6.6±0.4
Balanites aegyptiaca leaves	72.0±1.4	36.0±3.5	24.4±0.7	11.6±2.1	13.9±1.6
Balanites aegyptiaca pods	48.6±3.3	65.0±4.4	40.5±2.3	24.5±0.9	11.5±0.3
Barleria acanthoides	48.5±1.3	58.6±2.1	46.3±2.9	12.3±1.5	20.1±0.7
Cynodon dactylon	48.5±0.8	74.0±7	38.5±5.0	35.5±2.3	13.4±1.4
Eucleadivinorum	76.6±0.8	32.4±1.3	28.3±0.4	4.1±0.8	19.5±0.4
Lyciumeuropeum	81.6±0.3	34.2±2.1	15.7±0.9	18.5±1.7	7.0±1.5
Pollichia campestris	43.4±0.2	73.6±1.9	47.8±2.8	25.8±1.9	18.5±2.0

NDF-Neutral detergent fiber, ADF-Acid detergent fiber, ADL- Acid detergent lignin, IVDMD-*In vitro*-dry matter digestibility

3.5 Discussions

The camels in this study were able to spread over a large area and encountered a wide variety of forage species. Trees dominated the camel diet during the wet season but declined during the dry season when most of the species shed off their leaves. Grass species made a small portion of the preferred forages, which was attributed to the high abundance of other forage species and trees, rather than grasses. The camels could select the tender twigs from the thorny and small branches in the wet season as well as nibble leaves and pods of in the dry season due to its thick lips and a cleft on the upper lip (Amin *et al.*, 2011). Due to its long neck, the camel was able to browse on trees up to 3m above the ground. Their specific forage preference and feeding at higher levels above the ground minimized the direct competition with cattle, sheep, and goats (Mohammed *et al.*, 2020). In the dry season, there were no fruits available and camels spent nearly 80% of the grazing time on the five most preferred forage species, unlike wet season where the camels could browse and graze on other varieties of forages.

The forage preference by camels in this study corroborated with previous findings reported by Laudadio *et al.*(2009) and Abukashawa *et al.* (2016), who reported that camels tend to browse on trees more than they graze on grasses. Similarly, Field & Kariuki (2005) reported the average composition of forages browsed by camels as 50% dwarf shrubs, 25% trees, 14% herbs, and 11% grass in Marsabit County, Kenya. Chimsa *et al.*(2013) also reported that camels prefer to browse on shrubs and trees, but they also graze on herbs and annual grasses. Camels were reported to prefer shrubs, which constituted over 90% of their diets in the wet season (Kuria *et al*., 2012). Moreover, Kuria *et al.*(2005) study on preferred forage species by camels in North Eastern Kenya reported that they spent more than 80% of their time in the range browsing on dicotyledons than grazing while during the dry season, they spent 71-100% of their grazing time in the range on approximately seven forages. In the dry season, Alkali *et al.*(2017) reported that camels browse on green tips of trees.

Camels are more selective in their diet during the wet season when the forages are in plenty and indiscriminative in the dry season due to forage scarcity (McLeod & Pople, 2008; Amin *et al*., 2011). Forage preference in camels depends on the season, amount, nutritive content, and type of forage species available in the range (Shaheen, 2005; Abebe *et al.*, 2012).

This study found that *Euphorbia tirucalli* as a forage browsed on by camels in the dry season which was also regarded as a vital camel's forage during drought seasons in Borana, Northern Kenya (Kagunyu & Wanjohi, 2015). The acacia spp., *Balanites aegyptiaca*, *Lycium europaeum*, and *Barleria* spp. were also observed to be among the most preferred forage species by Kuria *et al.*(2004) in North Eastern Kenya. *Balanites aegyptiaca* and *Barleria acanthoides* were listed as the most common forage species preferred by camels in Karamonja Uganda (Salamula *et al.*, 2017). Additionally, *Balanites aegyptiaca* emerged among the preferred browses by camels in the north western Nigeria (Alkali *et al.,* 2017). *Balanites aegyptiaca* is evergreen, large woody tree and of highly nutritive value in all seasons (Schwartz *et al.,* 2012). *Opuntia* was highly ranked as the preferred forage in the dry season by dromedary camels in Eastern Ethiopia (Desalegn & Mohammed, 2012).

The dry matter (DM) content in forages is the actual amount of matter after the loss of moisture, bases, and volatile acids (Ghazanfar & Latif, 2011). The DM content in this study (20.5±0.2% to 72.2±0.1%) had lower ranges than those reported by Abdullah *et al.* (2017) in most browsed forage in Cholistan desert, Pakistan. The CP content of 17.9% in the *Acacia seyal* recorded in this study was lower than the CP content of 31.05% and 34.6% reported by Kefyalew, (2015) respectively but similar with 17.56% of (Eiman *et al.*, 2016). The CP content of 12.5% in

Balanites aegyptiaca and 10.4% in *Cynodon dactylon* noted in this study was lower than the CP content of 17.94% and 18.56%, respectively reported by (Eiman *et al.*, 2016). The CP content range in this study (7.4±0.8% to 25.7±1.2%) had similar ranges as those stated by Sagala *et al.* (2020) for browsed forages by lactating camels in the peri-urban of Marsabit, in Kenya. It was also found almost consistent with the previous study of Desalegen & Mohammed (2012), on browsed species by dromedary camels in Eastern Ethiopia. However, the findings of this study were higher than the values reported by Kuria *et al.*(2005) and Kuria *et al.*(2012), who reported ranges of 12.1±3.7% and 3.7 to13.2 %, for the most preferred forage species by camels in Upper Eastern Kenya and North Eastern Kenya, respectively. On average, the protein concentration of the species selected by camels is greater than for other livestock (Lusigi *et al.*, 1984). The CP content was higher than the documented minimum level of 7-8% essential for rumen function and optimal feed intake by ruminant animals (Van Sost, 1994). It, therefore, indicates that the most browsed species were of high nutritive value.

Ash shows the mineral content in the forage mostly calcium, phosphorus, potassium, and trace elements. In our results, ash content ranged from 5.9 to 22.9% while calcium and phosphorus ranged from 0.7 to 3.4% and 0.1 to 0.3% respectively. Different researchers have reported different ash and mineral contents of various forage species browsed and grazed by camels (Kuria, 2004; Ganskopp & Bohnert, 2014). The ash content ranged reported in this study was similar to the values reported by Lakhdari *et al.*(2015), who determined 15 to 27% ash for forage species preferred by dromedaries in arid rangelands of Algeria. The calcium and phosphorous content in this study were comparable with Desalegen & Mohammed (2012), findings on browsed species by dromedary camels in Eastern Ethiopia. The similarity could be that camels prefer halophytic forages that have high ash concentrations (Medila *et al.*, 2015). Camels prefer forages with high mineral content, especially forages high in calcium even where such forages are poor in phosphorus (Towhidi, 2007; Medila *et al*., 2015).

Forage quality is one of the factors that contribute to animal performance which is also highly influenced by both neutral detergent fiber (NDF) and *in vitro* dry matter digestibility (IVDMD). A high concentration of NDF reduces the neutral detergent soluble which include; crude protein, fat, sugar and starch. The NDF concentration of *Acacia seyal* 29.1%, *Lycium europaeum* 34.2%, *Euclea divinorum* 32.4%, and *Balanites aegyptiaca* 36% in this study were within the normal range of 30-40% of nutritious fodder for animals (El Shaer & Gihad, 1994). The relatively low NDF concentration is reflected in the higher *in vitro* dry matter digestibility reported making them more palatable. The *in vitro* dry matter digestibility was 64.2% in *Acacia seyal,* 81.6% in *Lycium europium*, 76.9% in *Euclea divinorum,* and 72% in *Balanites aegyptiaca*. This confirms the report of Kidake, (2016) which states that there is a high correlation between NDF and digestibility. Digestibility of forages and NDF are negatively correlated (Mohammadabadi , 2019). Low NDF concentration is a characteristic of good forage quality and high *in vitro* dry matter digestibility (Jassim, 2017), with an expected positive effect on camel performance (Bakshi& Wadhwa, 2004; Osuga *et al.*, 2008). According to the studies of Zinn *et al.* (2004) and Mohammadabadi , (2019), high NDF content in forages limits energy intake and reduces nutrient digestibility thus affecting animal performance.

The *Acacia seyal* fiber fractions of 29.1% NDF and 15.2% ADF recorded in this study were comparable with the range of 20-35% NDF and 12-25% ADF (Heuze *et al*., 2015). *Acacia seyal* in Baringo County was reported to contain 23% NDF and 16.8% ADF respectively (Abdulrazak *et al*., 2000). Similarly, Eiman *et al.* (2016) study reported 29.11% NDF, 28.91%

NDF, and 66.75% NDF in *Acacia seyal, Balanites aegyptiaca* and *Cynodon dactylon* respectively.

The relatively high NDF concentrations of *Barleria acanthoides* (58.6%), *Pollichia campestris* (73.6%), *Balanites aegyptiaca* pods (65%), and *Cynodon dactylon* (74%) reflected in the relatively low *in vitro* dry matter digestibility observed for *Barleria acanthoides* (48.5%), *Pollichia campestris* (43.4%), *Balanites aegyptiaca* pods (48.6%), and *Cynodon dactylon* (48.5%). However, no obvious signs of poor performance in camels were noted. Camels have high capacity of utilizing fibrous feed resources by increasing rumen retention time for more digestion (Lechner-Doll *et al.*, 1990). Moreover, camels have ruminal microflora that adapts to high levels of urea cycling, active rumination and digestion of varieties of forages therefore able to digest roughages of low quality (Fattah *et al.*, 1999). Camels can survive on low-quality fibrous roughages compared to other livestock species, as they can extract more energy from the feed they consume (Degen *et al.*, 1987), enabling them to survive droughts.

The chemical composition and *in vitro* dry matter digestibility of forage species preferred by camels in this study varied slightly with documented forages in previous literature. The variation may have been attributed to the difference in geographical location, available forages, and soil type (Lee,2018). Lee, (2018) reported that forages in hot and dry regions have lower nutritive quality than forages in cool and wet regions because of physiological and phonological changes induced by the warmer climate and species turnover.

3.6 Conclusion

The most preferred forages were relatively high in crude protein, calcium, ash, *in vitro* dry matter digestibility and lower in neutral detergent fiber concentrations, indicating that forage nutritive value affected the forage preference by the camels.

3.7 Recommendations

There is need to strengthen the knowledge of camel keepers on the preferred forage species during the wet and dry seasons. The study recommends conservation of the most preferred forages to optimize grazing management and supplementation for lactating camels, particularly during dry seasons.

CHAPTER 4

4 EFFECTS OF SUPPLEMENTING LACTATING SOMALI CAMELS WITH *OPUNTIA STRICTA* AND COTTON SEED CAKE ON FEED INTAKE AND MILK YIELD.

4.1 Abstract

Opuntia has been used as forage feed for livestock during dry seasons. In Kenya, *Opuntia* has invaded ASALs conservation areas, rangelands and cultivation areas covering hundreds of acres of land as a noxious weed with negative environmental impacts. The study was therefore conducted to determine the effects of supplementing lactating Somali camels with *opuntia stricta* and cotton seed cake on feed intake, milk yield and composition. Eight Somali lactating camels were selected and fed for 84 days using Latin square design to determine the effects of supplementing lactating grazing camels with *Opuntia stricta* and cotton seed cake on feed intake, milk yield and milk composition. The supplements were offered to camels after grazing in the range for four hours. The four treatments were: grazing only which was the control; grazing supplemented with *Opuntia stricta* only; grazing supplemented with *Opuntia stricta* plus cotton seed cake; grazing supplemented with cotton seed cake only. The young cladodes, mature cladodes, and cotton seed cake were analysed for their chemical composition, fiber fractions and *in vitro* digestibility. The feed intake was determined in both the dry matter and crude protein intake. The milk yield was determined using a digital weighing balance and milk composition using the Lacto-scan milk analyzer system. The young cladodes reported higher crude protein (15.8%), ether extract (2.5%), calcium (2.4%) and phosphorus (0.4%) than the mature cladodes which recorded, crude protein (4.4%), ether extract (1.6%), calcium (1.7%), and phosphorus (0.2%) in dry matter basis. There was no difference in daily dry matter intake between camels fed on the different supplemental diets ($P > 0.05$). The milk yield and milk composition were not

affected by the treatments. The study concluded that young cladodes were nutritionally superior to the mature cladodes. It recommended supplementation of both the young and mature cladodes to counteract the nutritional difference.
Keywords: *Opuntia stricta*; Cotton seed cake; lactating camels; chemical composition; *in vitro* digestibility

4.2 Introduction

The reported milk production of camels in Kenya is below their genetic potential (Gikonyo *et al*., 2018). This has been attributed to the fact that they are kept for subsistence rather than commercial purposes and therefore receive no feed supplementation (Aljumaah *et al*., 2012). The Somali camel breed produces an average of 5 to 8 liters of milk per day (Bekele *et al*., 2002; Farah & Fischer, 2004; Farah *et al*., 2007). In favorable conditions during the peak of lactation, the breed can produce between 12–20 liters per day under intensive systems (Farah *et al*., 2007). In Kenya, camels under pastoral management systems yield 2.4 to 7 liters a day and with better feeding, milk yield can improve to over 10 liters of milk per day (Onjoro *et al*., 2006). Little work has been done on the effects of supplementary feeding on milk production. Dereje *et al*. (2015) in their study reported a considerable increase in milk yield and milk fat in free ranging dromedary camels when they consumed supplementary concentrate feed prepared from a mixture of sorghum grain, wheat bran, noug seed cake and mineral vitamin premix in amounts of 0.5 and 0.75 kg per kg milk.

Cactus is regarded as a noxious weed that degrades land, with dangerous and poisonous spines that cause mortality to domestic and wild animals (Githae & Nyangito, 2010; Githae, 2018). Pastoralists claim that consumption of prickly pear fruit by livestock may cause death (Larsson, 2004). It forms dense shrubs restricting human access to areas under the plant (Shackleton *et al*., 2017). Brolin (2004) noted decreased plant diversity with increased *O. stricta* density. Its infestation also have negative effects on aesthetics and recreation in inhabited areas (Nikodinoska *et al*., 2014). Local communities in Baringo, Kenya belief that Cacti causes degradation of land and desertification (Kang'ara & Gitari, 2008).

Despite the observations above, *Opuntia* is an important crop for developing countries in ASALs because of its multiple purpose usage (Mashope, 2007). *Opuntia* has been used as a forage drought feed for livestock and often for emergency feeding in ASALS regions of the world (Taasoli & Kafilzadeh, 2011; Agropecu, 2018; Gebremedhn, 2018). This is due to the ability of *Opuntia* to remain nutritious and productive in water deficit conditions (Nobel & Zutta, 2008). It therefore, provides the much-needed water, vitamins, and energy in the dry seasons (Kang'ara & Gitari, 2008).

According to Vazquez *et al*., (2017), prickly pear have been utilized extensively for fodder in northern Mexico ASALs. The *Opuntia* is processed by completely crushing the spines in the cladodes or pads to produce a thick pulp that is fed to animals or removal of spines through bonfires (Kang'ara and Gitari, 2010). Cacti produce large quantities of forage throughout the year when properly managed.

Opuntia cladodes lack sufficient crude protein and protein supplementation is necessary (Mashope, 2007). For the past years, studies have shown that the utilization of prickly pear in ruminant diets can only replace the conventional feeds partially. Therefore, this study evaluated the effects of supplementation of lactating camels with *Opuntia stricta* and cotton seed cake on feed intake, milk yield and milk composition.

The specific objectives of this study were:

1. To determine the dry matter and crude protein intake of lactating Somali camels fed on *Opuntia stricta* and cotton seed cake
2. To determine the effects of supplementing lactating dairy camels with *Opuntia stricta* and cotton seed cake on milk yield and milk composition.

4.3 Materials and Methods

4.3.1 Study site

As described in chapter three.

4.3.2 Study Design

4.3.2.1 Experimental Animals

Eight lactating Somali camels were selected from different herds through visual assessment for healthy camels. The camel owners provided camels of parity one to three and in early stage of lactation with a healthy calf. The experimental camels were ear-tagged with a Button electronic ear tag, Raybaca brand, model RBC-ET01 LF for identification and dewormed before the start of the experiment. They were sprayed once a week to get rid of ectoparasites. They were divided into two blocks, four camels each block. The camels had calved within 1-4 months, that is, early lactation and had a parity of between 1 and 3. The camels were housed individually and were fed on individual feeding troughs. They were kept on the experimental feeds for 84 days. Initial and final body weights were obtained by weighing the camels using a weighing band. The body weights were estimated to the nearest 0.1 kg by the following formula: abdominal girth (m) * heart girth (m) * shoulder height (m) *50 as a factor (Schwartz *et al.*, 1983). All calves were kept together in a separate pen.

4.3.3 Feeding Management

The camels were allowed to graze or browse on rangeland for 8 hours per day from 10:00 am to 6:00 p.m. They were supplemented with experimental diets for 3 to 4 hours at night before the first milking which was done at 10.00 p.m. Diets were offered in separate feed trough compartments (Plate 4.1). The cactus pads were harvested at randomly selecting the spineless pads every two weeks (Plate 4.2). They were stored in sacks under a shade. Water was sprinkled on stored cactus frequently to maintain the moisture content.

The selected spineless pads were chopped daily (Plate 4.3), and weighed to allow for 3kg DM of cactus per camel per day. For the treatment that consisted of cactus and cotton seed cake, cactus and cotton seed cake were mixed before feeding. Common salt was added to the experimental diets and offered *ad libitum* to the camels on control treatments throughout the experimental period. Leftover feed was collected and weighed at 2100h. During weighing, the cotton seed cake was separated from the cactus for the experimental diet that consisted of both cactus and cotton seed cake. The refusals were weighed using a digital electrical weighing scale and recorded. Feed offered and refused each day was measured and recorded individually.

Plate 4.1: Separated individual feed trough compartments for feeding camels the supplement

Plate 4.2: Selectively harvested *Opuntia stricta* cladodes

Plate 4.3: Chopped *Opuntia stricta* cladodes before feeding

4.3.4 Experimental diets

Four supplemental treatments were used in this study. The treatments are shown in Table 4.1 and Plate 4.4 below:

Table 4:1: Table indicating how supplemental diets were offered

Treatment number	Feeding regime
1	Grazing in the rangeland (Only)(Control)
2	Grazing + supplementation with cactus *Opunti astricta* (3 kg DM)
3	Grazing + supplementation with cactus (3 kg DM) and cotton seed cake (3 kg)
4	Grazing + supplementation with cotton seed cake (3 kg)

Plate 4.4: Cotton seed cake treatment (left) and *Opuntia stricta* plus cotton seed cake treatment (right)

4.3.5 Experimental Design

The experiment was set in a Latin Square Design with four treatments (diets), two blocks, four camels each block. The four dietary treatments were assigned randomly to camels in each block. Each diet treatment was fed for a period of 21 days for each camel and samples were collected from 14th day of feeding. The camels were fed on the supplementary diets *ad libitum* from 6.00 P.M to 10.00 P.M when they were milked.

Each diet was fed to four camels in a double Latin square experimental design for a period of 21 days as shown in Table 4.2 below.

Table 4:2: Treatment regimen

	Block 1			
Camels/Day	1	2	3	4
1– 21	Treatment 1	Treatment 2	Treatment 3	Treatment 4
22 –42	Treatment 4	Treatment 3	Treatment 2	Treatment 1
43– 63	Treatment 3	Treatment 4	Treatment 1	Treatment 2
64– 84	Treatment 2	Treatment 1	Treatment 4	Treatment 3

	Block 2			
Camels/Day	5	6	7	8
1– 21	Treatment 4	Treatment 3	Treatment 2	Treatment 1
22 –42	Treatment 1	Treatment 2	Treatment 3	Treatment 4
43– 63	Treatment 2	Treatment 1	Treatment 4	Treatment 3
64– 84	Treatment 3	Treatment 4	Treatment 1	Treatment 2

4.3.6 Sampling Procedure

Fresh samples of cactus were weighed during every harvest using an analytical digital balance single pan, to determine the dry matter content of every period of the study. Young cladodes of less than one month from the time they sprouted were harvested as well as mature cladodes for laboratory analysis. The cotton seed cake was sampled from every sack used in the trials and packaged in khaki bags. The cactus were packaged in a carton and transported 270km to the Animal Nutrition Laboratory, ISO 9001: 2015 certified, of the University of Nairobi for analyses.

4.3.7 Milk production by camels

Calves were used in milk-let down stimulation followed by hand-milking four times daily.

Milking was done at 10:00 pm, 2:00 am, 5:30 am and 9:30 am. Daily milk produced was weighed and recorded. Milk production was monitored throughout the experimental period. Determination of milk quantity was done by weighing using a calibrated litter-can for milk volume and analytical digital weighing balance single pan for milk weight. Daily milk density was calculated from milk weight (kgs) divided by milk volume (liters converted to a cubic meter by * 1000).

4.3.8 Milk composition of camel milk

Camel milk samples were collected in the last eight days of each period of study. They were collected in the morning hours, i.e., milk collected at 5:30 am and 9:30 am were pooled. The milk from each camel was put in triplicate in 50 ml falcon tubes. Lacto-scan Milk Analyzer was used according to the manufacturer's instructions to obtain the milk composition. The parameters included; milk protein, milk fat, lactose, density, salts and solids not fat content in milk. Total solids were determined by calculation of milk fat plus solids not fat. Milk composition was analyzed at the milking site. However, a few milk samples were transported to the University of Nairobi for laboratory analysis and compared with the Lacto-scan milk analyzer readings.

4.3.9 Laboratory Analysis

Determination of moisture content was done as described in section 3.2.4.1, while proximate analysis was done as described in Section 3.2.4.2. The contents of minerals, fiber and digestibility of feeds were done as described in section 3.2.4.3.

4.3.10 Data Analysis

Data was entered in Microsoft Office Excel 2010 datasheet. It was imported to Genstat Version 14 (Genstat Dicovery, 2007). Data on dry matter and crude protein intake were subjected to analysis of variance (ANOVA) (Clewer and Scarisbrick, 1991) to generate ANOVA table. Significant means and corresponding standard errors were separated by Tukey's test.

4.4 Results and Discussion

4.4.1 Chemical Composition of diet ingredients

Table 4.3 shows the chemical composition of the dietary ingredients.

Table 4:3: Chemical compositions (%DM) of dietary ingredients fed to lactating camels

Ingredient	DM	CP	EE	Ash	Ca	P
Co tton Seed Cake	88.9	29	8.5	5.3	0.7	0.7
Mature Cladodes	13.8	4.4	1.6	18.9	1.7	0.2
Young cladodes	5.5	15.8	2.5	15.6	2.4	0.4

DM-Dry matter, CP-Crude protein, EE- Ether Extracts, Ca-Calcium, P-Phosphorus

The chemical composition (Table 4.3) showed that mature cladodes had a dry matter content of 13.8%, 4.4 % crude protein, 1.6% ether extract, 18.9% ash, 1.7% calcium, and 0.2 % phosphorous. The young cladodes had 5.5% dry matter, 15.8% crude protein, 2.5% ether extract, 15.6% ash, 2.4% calcium and 0.4% phosphorous. The nutritional quality of cactus pear varied since the cladodes were at different stages of development. Young cactus pear cladodes were reported to be nutritionally superior to the more mature ones (Syomiti *et al*., 2014). The dry matter of the mature cladodes in this study was slightly higher than Grünwaldt *et al*., (2015) who evaluated varieties of *Opuntia* species and determined their nutritive value for livestock feeding and reported *Opuntia* pads to have a mean of 11.3% DM. However, the 4.4% CP of the mature cladodes was within the range of 2-6% CP as reported by (Grünwaldt *et al*., 2015). Additionally, the results were comparable to (Cruz-hernandez & Paredes-lopez, 2006;Salem *et al*., 2009; Kawas, 2011; Mostafa, 2015; Rodrigues *et al*., 2016) findings who reported high contents of calcium of 1.9-4.1%, 10-20%DM, ash 15-25%DM, 6.6-9.13%CP, 1.15-1.41%EE and 0.2%P in different types of cactus respectively.

The higher DM content of mature cladodes was reported earlier (Syomiti *et al*., 2014) and is expected due to decreased moisture content. The young cladodes had higher ether extract content

(2.5%) than the mature cladodes (1.6%). Total fat content decreases with the age of cladodes (Rodríguez-Garcia *et al*., 2007; Hernández-Urbiola *et al.*, 2011). The mature cladodes had higher ash content (18.5%) than the young cladodes (15.6%). This contradicts Syomiti *et al*., (2014) and Ribeiro *et al*. (2017) who noted that young cladodes were richer in ash content.

Young cladodes contained higher crude protein, calcium, and phosphorus; 15.8% CP, 2.4%Ca, 0.4%P than the mature cladodes; 4.4%CP, 1.7%Ca and 0.2%P respectively. Younger cladodes have higher protein and mineral contents while crude fiber content is lower (Velázquez *et al*., 2010; Ribeiro *et al*. 2017). This is because the absorbed nutrients are mobilized to the young tender cladodes than to mature cladodes (Pinos-Rodríguez *et al*., 2008). In the contrary, Rodríguez-Garcia *et al*., (2007) and Hernández-Urbiola *et al.*, (2011) studies reported linear increase in crude protein, crude fiber, total carbohydrates and mineral content with maturity of cladodes. The variation in the results of different studies could be due to genetic variability, season, age, part of the plant, fertilization, and harvesting management (Mostafa, 2015; Abel *et al*., 2017; Lopes, 2018).

4.4.2 Fiber fractions and *In vitro* dry matter digestibility of dietary ingredients

The fiber fractions and *in vitro* dry matter digestibility (%) of dietary ingredients are diets for lactating camels are shown in Table 4.4.

Table 4:4: Fiber fractions and *in vitro* dry matter digestibility (%DM) of dietary ingredients fed to lactating camels

Dietary ingredient	NDF	ADF	ADL	IVDMD
Cotton Seed Cake	53.5	35.0	16.2	55.6
Mature Cladodes	22.8	9.9	5.1	86.6
Young cladodes	17.2	11.1	4.5	95.6

NDF-Neutral detergent fiber, ADF-Acid detergent fiber, ADL- Acid detergent lignin, IVDMD-In vitro-dry matter digestibility

The fibre content of mature cladodes were; 22.8% neutral detergent fiber (NDF), 9.9% acid detergent fiber (ADF), and 5.1% acid detergent lignin (ADL) respectively while the young cladodes had 17.2% NDF, 11.1% ADF, and 4.5% ADL. The fibre content of young cladodes were lower than mature cladodes in agreement with the Velázquez *et al*., (2010). In contrast, (Rodrigues *et al.*, (2016) noted that fresh cladodes contained 16.36 % ADF and 25.45%NDF. A study by Grünwaldt *et al*., (2015) reported that young cladodes have a crude fiber content of 8-15%DM with 28.5% neutral detergent fiber, 20.1% acid detergent fiber, 65% total digestible nutrients and 55.4% soluble carbohydrates. Velázquez *et al*., (2010) reported spineless *Opuntia* cladodes to consist of high starch content of 28% DM, the neutral detergent fiber of 38.7% and 4.9% acid detergent lignin. The fiber fractions varies with age (Velázquez *et al*., 2010;Ventura-aguilar *et al*., 2017). Velázquez *et al*., (2010) reported that organic matter, total carbohydrates and neutral detergent fiber increases with age. However, Ventura-aguilar *et al*., (2017)reported that soluble fiber decreases with age.

The study also noted a high *in vitro* dry matter digestibility of 95.6% in young cladodes and 86.6% in mature cladodes. Therefore, they could be good forage for ruminants. The results were higher than that reported by Salem *et al*., (2009) and Dubeux (2010) studies which reported *in vitro* dry matter digestibilities of 65% for mature cladodes. Bazie *et al.*, (2019) also reported a digestibility of 84% for 30 days old cactus but 66.7% for 3 months old cactus. *In vitro* dry matter digestibility decreases as the plant matures (Velázquez *et al*., 2010; El Otmani *et al.*, 2019).

4.4.3 Effect of inclusion of *Opuntia stricta* in camel's diet

The crude protein and dry matter intake from the supplemental ingredients by the lactating camels is shown in Table 4.5.

Table 4:5: Dry matter and crude protein intake (kg) of supplements by lactating Somali camels

Treatments	***O. stricta***	***O. stricta*+CSC**	**CSC**	**P-Value**
DM Intake	1.416±0.055 [a]	1.626±0.051 [a]	1.472±0.066 [a]	0.216
CP Intake	0.061±0.003[a]	0.07±0.002[a]	0.414±0.018[b]	<0.001

DM- dry matter, CP- crude protein, *O. stricta*- *Opuntia stricta*, CSC- cotton seed cake
[ab]Means are significantly different between treatments

The dry matter and crude protein intake from the supplements is shown in Table 4.5. There were no significant differences in the dry matter intake between the treatments. The CSC was high in DM (88%DM) as shown in Table 4.3 while *O. stricta* was lower. Therefore, irrespective of high *O. stricta* intake on "as is" the basis, the dry matter intake (DMI) was still low and close to that of CSC alone. There was no significant difference in DMI among the supplemental diets. However, camels fed on *O. stricta* plus CSC treatment had the highest DMI as it was the most preferred among the supplemental diets. It could be attributed to the low NDF in cactus, that is, 22.8%NDF in mature cladodes (Table 4.4) as camels were supplemented with mature cladodes. Low levels of NDF is an indicator of high neutral detergent soluble (NDS), (fat, sugars and starches) which is an indicator of high voluntary DM intake of the camels fed on *O. stricta* plus CSC (Felipe *et al.*, 2016).This agrees with the study by Degu *et al.,* (2009) study on supplementation of isonitrogenous oil seed cakes in cactus and straw in sheep which showed that supplementation of cactus with cotton seed cake and peanut cake resulted in better feed intake, daily body weight gain, feed conversion efficiency and dressed carcass weight compared to non-supplemented diets. Other scientists, Llorente *et al.*, (2011); Medeiros *et al.*,(2013) have reported decreased dry matter intake with proportional increase of forage cactus above 50% of a diet in ration formulation.

The camels supplemented with CSC consumed an average CP of 0.414kg per day compared to those supplemented with *O. stricta* (0.06kg/day) and *O. stricta* plus CSC (0.07kg/day) respectively. Although, CSC had high CP (29%) as indicated in Table 4.3 the CP intake in camels fed both *O.stricta* plus CSC still recorded low CP intake because the camels selectively fed on *O. stricta* leaving the CSC as refusal. There were significant differences in the crude protein intake among camels on different treatments. This is attributed to the low protein content of *Opuntia stricta* as shown in Table 4.3 and indication that livestock diets based on *Opuntia* should be supplemented with a source of crude protein (Mashope, 2007; Dubeux, 2010; Brandão & Costa, 2012).

Lactating camels require large quantities of water as milk is approximately 90% water. It was noted that the camels supplemented with *O. stricta* and *O. stricta* plus CSC barely consumed water. This agrees with Costa *et al.* (2009) who reported that water intake reduced with increased *Opuntia* intake. Additionally, Violeta *et al.*, (2017) noted that an increase in the amount of forage cactus in the diet caused a decrease in voluntary water intake and dry matter intake. Animals consume water either by drinking available water or from feeds, mostly succulent or moist foods (Garcia *et al*., 2010 and Vilela *et al*., 2010). Diet composition, therefore, contributes to water intake (Garcia *et al*., 2010). Violeta *et al.*, (2017) reported that *Opuntia* can sustain livestock without water for about 60 days in dry lands which experience water scarcity. In cattle, cactus helps to meet the animals' water requirements and reduces their voluntary water intake (Kawas, 2011; Violeta *et al*., 2017). Jilo & Tegegne (2016) found cactus pear substituted pasture hay at an optimal level of up to 60% which satisfied the water requirement of sheep.

Kawas(2011) noted that the water restriction on sheep fed *Opuntia* throughout the entire experiment did not have a negative effect on animal performance. Cardoso *et al*., (2018) also noted that the water requirements of the lamb fed cactus pear were met.

4.4.4 Milk yield and composition of lactating camels supplemented with *Opuntia* and cotton seed cake.

The milk yield and milk composition of lactating camels on different supplements are shown in Table 4.6

Table 4:6: Milk yield and composition of lactating camels fed *Opuntia stricta* and cotton seed cake

		Treatments				SEM	P-Value
		Control	*O. stricta*	*O. stricta* +CSC	CSC		
Quantity	**MV(liters)**	4.72	4.49	4.82	4.78	0.23	0.566
	MD (kg/L)	1.05	1.05	1.07	1.03	0	0.876
Quality	**% Fat**	4.23	4.36	4.32	4.23	0.06	0.85
	% SNF	5.97	6.03	5.97	6	0.05	0.97
	Density(kg/m^3)	1008.79	1008.4	1013.94	1004.65	2.5	0.63
	% Protein	2.37	2.4	2.37	2.38	0.02	0.976
	% Lactose	2.57	2.61	2.57	2.59	0.03	0.97
	% Salts	0.18	0.18	0.18	0.18	0	0.973
	% Total Solids	10.21	10.39	10.29	10.23	0.09	0.897

MD- Milk density (g/cm^3), MV- Milk volume (Liters)

4.4.4.1 Milk Yield

In this study, the average milk yield of the Somali camels was 4.5 liters daily per camel. There was no significant difference in yield between the treatments. The results were comparable to (Bekele *et al*., 2002; Farah & Fischer, 2004; Bekele *et al*., 2011; Riyadh *et al*., 2012; Babiker & El-zubeir, 2014; State, 2015). Somali camels produce an average of 5 to 8 liters per day (Farah & Fischer, 2004). The milk yield was similar to that reported for Sakuye camels which produce an average of 4 kg milk daily with a maximum of 12 kg (Bekele *et al*., 2011). A study by Riyadh *et al*. (2012) reported that the daily milk production of Somali camel was 4.8liters in the 16th week of lactation.

In this study, milking was done four times per day which is reported to yield more milk than milking twice a day. Milk yield depends on the number of milking per day (Bekele *et al*., 2002; Wernery *et al*., 2004; Ayadi *et al*., 2014; State, 2015). A study by Bekele *et al*. (2002) noted production of 6.77 liters of milk per day for camels milked four times.

The average 4.5 liters of milk per day produced by the camels was higher than that produced by the cows (0.5 to 1.5 liters) and goats (0.2 to 0.5 liter) per day browsing and grazing in the same region (Gikonyo *et al*., 2014). This is in agreement with Bekele *et al*. (2002); Farah *et al*. (2007); Bekele *et al*. (2011) who reported that that a camel produces more milk and for a prolonged period than other livestock species under harsh climatic conditions. In dry lands, the milk produced by a camel is six times that produced by indigenous cattle (Field & Kariuki, 2005). A study by Hussen *et al.,* (2008) also noted that the camels in Ethiopia produced far more milk than the local cows. This is attributed to the ability of a camel to survive in harsh climatic conditions (Gebreyohanes & Assen, 2017).

Supplementing the grazing lactating camels with *Opuntia stricta* and CSC did not have a significant effect in milk yield and milk proteins (Table 4.6). The milk yields were 4.49, 4.82, 4.78, and 4.72 liters of milk per day for grazing camels, and those supplemented with *O. stricta*, *O. stricta* plus Cotton seed cake (CSC), and CSC respectively. The camels supplemented with *O. stricta* produced the least milk (4.49 liters) which was slightly lower than those on the grazing treatment without supplementation (4.72 liters). Camels fed *O. stricta* and CSC had a slightly higher milk yield (4.82 liters). The relatively high milk yield in camels fed *O. stricta* and CSC (4.82 liters) could be attributed to high dry matter intake compared to other treatments (Table 4.5).

Opuntia has high soluble carbohydrates contents like pectin that ferments rapidly in the rumen (Mehari *et al*., 2016; Araujo *et al*., 2017). The high digestibility of *Opuntia* (Table 4.4) (95.6% IVMD in young cladodes and 86.6% in mature cladodes) increased degradability rates of neutral detergent fiber, crude protein and dry matter, therefore promoting the camel milk yield (Menezes *et al*.,2010; Medeiros *et al*., 2013). Milk production is mainly influenced by dry matter intake and nutrient quality of a feed (Bekele *et al*., 2002; Farah *et al*., 2007; Mario *et al*., 2008). Therefore, utilization of forage cactus does not only increase digestibility of nutrients but also improves animal performance (Kawas, 2011; Violeta *et al*., 2017).

There was a slight increase in milk yield in camels fed CSC (4.78 liters) compared to those which were only grazing (4.72 liters). This shows that the camels had sufficient crude protein intake while grazing to meet the camel's protein requirements for maintenance. Camels tend to prefer forages that are high in protein content (Table 3.2).

Supplementing grazing lactating camels with various supplements in this study did not affect milk yield significantly (Table 4.6), but other studies in different livestock have shown significant differences (Salem *et al.*, 2004; Kawas, 2011; Jilo & Tegegne, 2016; Cardoso *et al.*, 2018). Supplementation of cactus with *Atriplex nummularia* had a significant effect on the growth of Barbarine lambs (Salem *et al.*, 2004). One of the possible reasons why milk yields were not significantly affected by treatments in this study could be that the amounts of *O. stricta* supplemented did not reach optimal levels (Table 4.5). Jilo & Tegegne (2016) found that cactus pear could substitute pasture hay up to 60% in sheep and resulted in a slight significant increase in live weight gain. A study by Kawas, (2011) also showed higher weight gain in goats fed diets containing 30% to 50% of cactus. Cardoso *et al.*, (2018) also noted an improved nutrient utilization, microbial efficiency and growth performance of lambs fed diets containing spineless prickly pear up to 45% dry matter.

4.4.4.2 Chemical composition of camel milk

The chemical composition of milk from the lactating camels is shown in Table 4.6. There were no significant differences in all the parameters between treatments. Milk protein and milk fat in this study were slightly higher while total solids, milk lactose, and solids not fat (SNF) were lower than the values reported by Mal and Sena, (2007); Konuspayeva *et al.*, (2009); Al haj & Al Kanhal,(2010); Abba *et al.*, (2013); El-zubeir, (2014). Shuiep *et al.* (2014) stated that milk protein and milk fat increased with increased water consumption by lactating camels. The hydration status and type of forage-fed by a camel determines the milk fat, protein, and water content (El-zubeir, 2014). The camel milk fat content (4.23% to 4.36%) was within the range reported for dromedary camels which is between 1.2% and 6.4% (Asresie, 2014).

The camel milk fat, milk protein, and milk density were within the range reported by Farah & Fischer, (2004 and Elhassan *et al.*, (2015). The 3.6% milk lactose content observed in this study was within the range reported for camel milk (2.8 to 5.8 %) (Yadav *et al.*, 2015). The milk lactose content of camel milk remains constant from the first month to end of lactation. However, the camel milk lactose content is lower than cow's milk (Soliman, 2005; Mohamed, 2011; El-zubeir, 2014). The salt content was 0.18% and was noted to be constant in all treatments.

The variation in camel milk composition reported in this study when compared to other studies could have been influenced by the stage of lactation (Zekele, 2007; Riyadh *et al.*, 2012; Elhassan *et al*., 2015), season (Bhagiel, 2015), breed (Dowelmadina *et al.*, 2014), milk production potential (Mal and Sena, 2007), geographical locations, parity number and feeding conditions of the camels (Iqbal *et al.*, 2001; Faye *et al.*, 2008; Al haj and Al Kanhal, 2010; Hammadi *et al.*, 2010; Aljumaah *et al*., 2011; Ayadi *et al*., 2014; El-zubeir, 2014; Shuiep *et al.*, 2014; Bhagiel, 2015). In camels with high milk production potential, the milk protein content is high while milk fat is lower (Mal and Sena, 2007). The early stage of lactation had the highest means of milk composition and decreased with the advancement of lactation (El-zubeir, 2014) which could be due to increase in the water content of milk during the last stage of lactation. The total solids of camel milk vary with season and are lower in the hot season while the water content increases for the nourishment of younger calves (Bhagiel, 2015).

4.5 Conclusions

The nutritional quality of *Opuntia stricta* cladodes was affected by stage of growth with young cladodes being more nutritious compared with mature ones. Digestibility of both young and mature cladodes of *Opuntia stricta* relatively high but they were low in dry matter and protein contents. Supplementation of grazing lactating camels did not have a significant effect on the camel milk yield but there was a trend where camels supplemented with *Opuntia* and CSC had the higher yields followed by those supplemented with cotton seed cake.

4.6 Recommendations

There is a need for controlled camel feeding experiments aimed at generating data on daily feed intake by lactating camels which will assist in designing appropriate supplementation protocol. Further research should be done on optimal level of *Opuntia stricta* and cotton seed cake supplementation to grazing lactating camels.

CHAPTER 5

5 SENSORY EVALUATION OF MILK FROM CAMELS SUPPLEMENTED WITH CACTUS *(O. stricta)* AND COTTON SEED CAKE.

5.1 Abstract

Camels produce more milk and for prolonged periods compared to other livestock species under harsh climatic conditions. The objective of the study was to evaluate sensory characteristics of milk from lactating camels kept under traditional pastoralist management conditions and supplemented with *Opuntia stricta* and cotton seed cake. Milk was obtained from camels grazing and browsing in the range (control), supplemented with *Opuntia stricta* only, cottonseed cake only, *Opuntia stricta* and cottonseed cake. Cow and goat milk were obtained randomly. Sixty panelists were selected at random from different camel farming regions in Kenya, 100 km from the study site. Sensory evaluation was carried out using questionnaires with the camel farmers, secondary school students and shop attendants as panelists. Ten coded milk samples constituting of; cow milk, goat milk, and camel milk from camels supplemented with *Opuntia stricta* and cottonseed cake were provided. The perception of appearance, smell, mouth feel, and overall acceptability of each milk sample were checked and recorded in reference to a hedonic scale of 1 to 9 with 9 being extremely like and 1 extremely dislike. Camel milk had the lowest rating compared with cow milk and goat milk for all sensory attributes. In sensory attributes, only the overall acceptability and preference had a significant difference ($P<0.05$). Goat milk was more acceptable while camel milk from camels fed on *Opuntia stricta* was the least accepted. There is a need for further research to improve the sensory quality of camel milk.

Key Words: camels; milk; Sensory evaluation; *Opuntia stricta*

5.2 Introduction

5.2.1 Camel Milk Production

Kenya has the fourth largest camel population in the world (FAOSTAT, 2018). The country's camel population was estimated at 3.22 million in 2016, with an estimated annual milk production of 940 million liters in 2013 (FAOSTAT, 2018). Approximately 0.3% of that 940 m litres is produced in Laikipia County (Kimenye, 2008). Only about 12% of the Kenyan camel milk is marketed: 10% is sold in raw form to local consumers while urban consumers get 2%. Thirty eight (38) percent is consumed by the camel keeping households and their herders as food while the remaining 50% goes to waste (Akweya *et al*., 2012). The milk is consumed either fresh or fermented where it contributes up to 30% of the annual caloric intake of the camel keeping households (Farah *et al*., 2007). Therefore, it plays an important role in the nutrition of the pastoral communities (Elhadi *et al*., 2015)..

A camel produces more milk and for a prolonged period than other livestock species under harsh climatic conditions (Bekele *et al*., 2002; Farah *et al*., 2007; Gaddour *et al*., 2013). Recently, camels have increasingly gained importance among communities that did not hitherto keep them due to recurrent prolonged droughts in ASAL areas. The camels are kept as a climate adaptation strategy (Guliye *et al*., 2007; Opiyo, 2015; Watson *et al*., 2016). Camel milk is consumed for its medicinal properties and nutritional value (Llorente *et al*., 2011; Jilo & Tegegne, 2016; Bedada & Lakew, 2018). It is reported to be hypoglycemic with anti-cancer properties (Agrawal *et al*., 2003; Agrawal *et al*., 2005; Magjeed, 2005). It has high vitamin C levels at 25-60 mg/l which is almost three times that of cow milk (Ramet, 2001;Farah & Fischer, 2004; Farah *et al*., 2007; Farah, 2017). The high Vitamin C content in camel milk is important in ASAL areas where vegetables and fresh fruits, which are the main sources of Vitamin C, are rare. Camel milk is opaque white with a faint sweet odor and sharp taste (Abbas *et al*., 2013). Its opaque white color is due to the fats which are finely homogenized throughout the milk (Yadav *et al*., 2015). Moreover, it has the smallest fat globules (2.99 μm) compared to goat milk (3.19 μm) (Mansson, 2008). It is sweeter during the early lactation compared to subsequent lactations due to high lactose content in the early stage of lactation (Zekele, 2007; Riyadh *et al*., 2012). Camel milk sours slowly compared to cow milk and hence can be kept longer without refrigeration (Farah & Fischer, 2004;Field & Kariuki, 2005).

This study was therefore to determine the acceptability of camel milk from grazing lactating camels supplemented with *Opuntia stricta* and cotton seed cake and compare with milk from goats and cows. The frequency of consumption of camel milk in different areas of Laikipia County and other ASAL areas was also evaluated and comparisons made among gender and different age groups.

5.3 Materials and Methods

5.3.1 Study Site

Management of camels is as described in chapter three.

5.3.2 Sampling Procedure and Data Collection

5.3.3 Sensory evaluation

This was done through a structured questionnaire which was designed, pre-tested, and administered to panelists through a language translator. The panelists were mainly pastoral communities who consumed camel milk. However, others were from non-camel keeping counties but resided in the regions that produce camel milk in large quantities. Sixty (60) respondents were selected randomly from different camel farming regions of Kenya, within 100Km from the study site. That is; Laikipia North (20), Laikipia East (12), Laikipia West (11), Marsabit (6), Moyale (4) and others (7). The panelists were both male and female between the ages of 18-65years. The evaluation involved transportation of the milk samples from the research site to the panelists. It was done randomly in homesteads, shopping centres and secondary schools in Laikipia County.

The survey was within a three months period; four times at three weeks intervals. Ten coded boiled milk samples were provided to the same panelists. Each milk sample was 100 ml in a tumbler and drinking water was provided between samples. The samples constituted of; cow milk, goat milk, and camel milk obtained from camels grazing and browsing in the range (control), supplemented with *Opuntia stricta* only, cottonseed cake only, *Opuntia stricta* plus cottonseed cake. The cow and goat milk were obtained randomly. During the administration of questionnaires, the panelists were asked to indicate their gender, age, their sub-county of origin, and how often they consume camel milk and other questions as shown in the questionnaire (Appendix 1.0). Attributes for scoring the milk were; appearance, smell, mouth feel, and overall acceptability. The perception of each attribute was checked and recorded in a column against the attribute in reference to a hedonic scale of 1 to 9 as follows: 9- Like extremely;8 -Like very much;7- Like moderately; 6- Like; 5- Neither like nor dislike;4- Dislike;3- Dislike moderately;2- Dislike very much;1-Dislike extremely. Preference was either yes as 1 or no as 2.

5.3.4 Data Analysis

Data were entered in Microsoft Office Excel 2010 datasheet. Data from the questionnaires was imported to Statistical Programme for Social Sciences (SPSS). Data on gender, treatments, and various attributes were subjected to analysis of variance (ANOVA) (Clewer and Scarisbrick, 1991) to generate ANOVA table. Significant means and corresponding standard errors were separated by Tukey's test.

5.4 Results and Discussion

The consumption frequency of camel milk by different panelists is shown on figure 5.1

5.4.1 Sensory Evaluation of camel milk

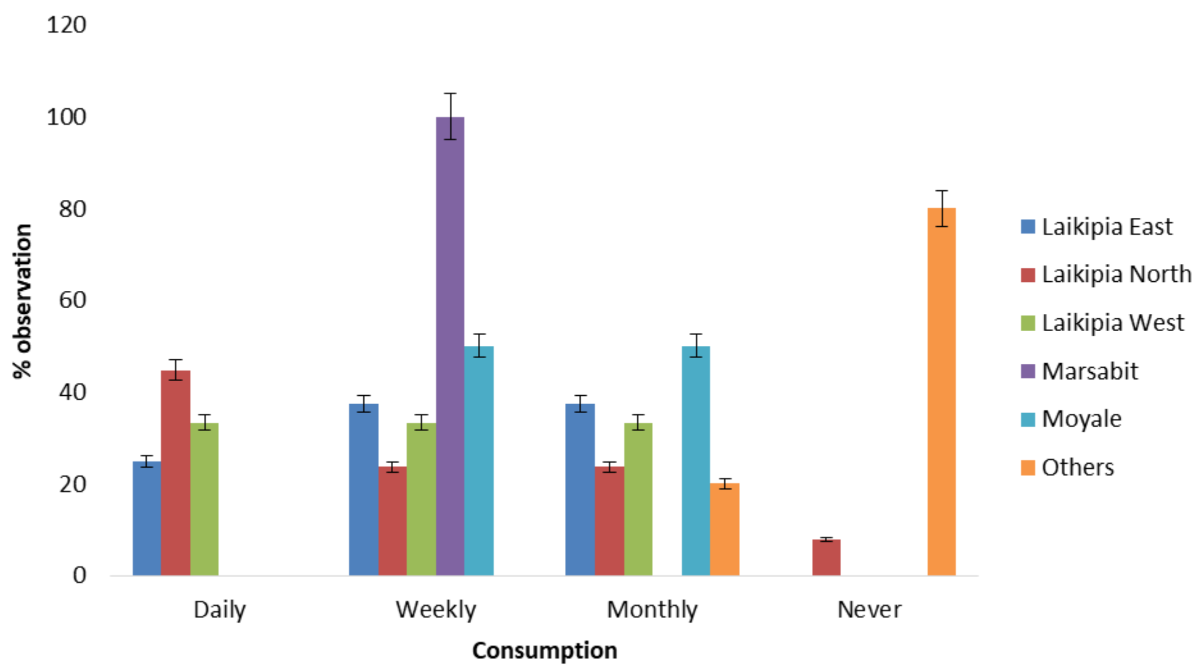


Figure 5.1: Bar graph showing consumption frequency of camel milk by the panelists in different sub-counties and counties

The panelists were from camel keeping communities (Figure 5.1). Laikipia North had the highest number of panelists who consumed camel milk daily, followed by Laikipia West and Laikipia East. Some of the panelists who were from the other counties that keep camels but resided in Laikipia County at the time of survey were from Marsabit and Moyale Counties, and most consumed camel milk weekly. Others who were from counties that don't keep camels but were living in camel keeping counties had never tasted the camel milk and a few consumed once in a month. This can be attributed to inadequate access to camel milk as urban consumers only get 2% of the total milk produced (Akweya *et al*., 2012).

Table 5.1 shows camel milk consumption by gender and age

Table 5:1: Consumption of camel milk by gender and age

Age	Consumption	Gender			
		Male	**N**	**Female**	**N**
Below 35	Daily	28.6	6	28.6	6
	Weekly	42.9	9	35.7	7
	Monthly	21.4	5	35.7	7
	Never	7.1	2	0	0
Above 35	Daily	5.6	1	91.7	7
	Weekly	27.8	3	0	0
	Monthly	38.9	4	0	0
	Never	27.8	3	8.3	1

At the age below 35 years, both females and males had equal (28.6%) frequency of daily camel milk consumption. This is in agreement with Akweya *et al*., (2012) that 38% of total camel milk produced in Kenya is consumed by the camel keeping households and their herders as food. The males who reported that they consumed milk weekly were the highest (42.9%) while the rest (21.4%) consume monthly and 7.1% had never consumed. On the other hand, camel milk consumption by females on weekly and monthly basis was 35.7% respectively. At the age above 35 years, females had the highest daily camel milk consumption of 91.7% who regarded camel milk as easier to digest than goat milk (Cardoso *et al.*, 2010) and the rest (8.3 %) had never taken camel milk. In male above 35 years, the highest frequency of camel milk consumption (38.9%) was monthly, 27.8% weekly, 27.8% had never drank the milk while a small portion (5.6%) consumed daily. This high daily intake by females was attributed to being keen on the numerous nutrients in camel milk that promote the body's natural defenses and hence considered a good source of protein, calcium, phosphorus, vitamin C, and niacin to meet part of the human's daily nutritional needs (Ramet, 2001; Farah & Fischer, 2004; Farah *et al*., 2007; Panwar *et al.*, 2015;

Farah, 2017). Within males, it was reported that they only took camel milk for the enhancement of immune defense mechanism (Wernery, 2006).

Table 5.2 shows weighted means of milk attributes between male and female. The means were based on hedonic scale ((1-9) with 9 being like extremely and 1 dislike extremely

Table 5:2: Comparison of various attributes of camel milk among men and women

Attribute	Gender	N	Mean±SE	P-Value
Appearance	Male	32	6.775±0.178	0.093
	Female	28	7.112±0.067	
Flavor	Male	32	5.184±0.166	0.014
	Female	28	5.876±0.191	
Mouth Feel	Male	32	5.019±0.132	0.006
	Female	28	5.804±0.212	
Smell	Male	32	5.019±0.14	0.000
	Female	28	6.06±0.147	
Preference	Male	32	1.406±0.022	0.000
	Female	28	1.221±0.03	
Overall acceptability	Male	32	5.388±0.168	0.029
	Female	28	5.984±0.186	

Hedonic scale; 9- Like extremely;8 -Like very much;7- Like moderately; 6- Like; 5- Neither like nor dislike;4- Dislike;3-Dislike moderately;2-Dislike very much;1-Dislike extremely. Preference was either yes as 1 or no as 2.

Females liked the camel milk more in all attributes assessed than males. In sensory attributes such as; smell, mouthfeel, flavor, preference and overall acceptability, there were significant differences ($p<0.01$), where females scored camel milk higher than males. Appearance was the only attribute where there were no differences scoring by men and women (7.1) which could be associated with its opaque white color making it appealing to the sight (Abbas, 2013).

Table 5.3 compares sensory and physical attributes of milk from camels fed different diets, with that of goats and cows.

Table 5:3: A table showing the mean comparison of treatments against various attributes

Treatment	Attribute					
	Appearance	Flavor	MouthFeel	Preference	Smell	Overall acceptability
O.stricta	6.983±0.289	5.357±0.548	5.164±0.307	1.367±0.088 [b]	5.46±0.277	5.185±0.385 [a]
O.stricta+CSC	6.929±0.178	5.418±0.519	4.989±0.337	1.386±0.111 [b]	5.285±0.45	5.689±0.491 [ab]
Grazing only	6.472±0.077	4.917±0.382	5.077±0.265	1.395±0.113 [b]	5.106±0.412	5.189±0.44 [a]
CSC	7.098±0.312	5.309±0.554	5.085±0.362	1.347±0.106[b]	5.388±0.316	5.576±0.342 [a]
Cow	6.699±1.235	5.833±0.833	6.086±0.514	1.285±0.251[ab]	5.674±0.96	5.91±0.624 [ab]
Goat	6.808±0.558	6.414±0.014	6.385±0.151	1.088±0.055[a]	6.024±0.19	6.746±0.146 [b]

[ab] means within a column are significantly different ($P \leq 0.05$)
Hedonic scale; 9- Like extremely;8 -Like very much;7- Like moderately; 6- Like; 5- Neither like nor dislike;4- Dislike;3- Dislike moderately;2- Dislike very much;1-Dislike extremely. Preference was either yes as 1 or no as 2.

Good quality milk should have a pleasantly sweet and clean flavor without a distinct aftertaste. Camel milk had the lowest rating compared with cow and goat milk for all attributes evaluated. Goat was scored highest in flavor, mouth feel, preference, smell and in overall evaluations while cow milk was rated second in flavor, mouth feel, preference, smell and overall acceptability.

The results were in agreement with Hashim (2002) who reported significantly lower ratings on taste, aroma and overall acceptability of camel milk compared to cow milk. This was expected as camel milk has lower lactose content and higher levels of magnesium, iron, copper, potassium, zinc, sodium and manganese than cow's milk. The latter is attributed to the high concentration of salt in camel milk (Hashim, 2002). The high mineral content in camel milk compared to cow milk is influenced by the somatic cell count (Mohamed, 2011). This is because the macrophages secrets lipolytic enzymes that degrades milk fat of a dromedary camel increasing differential somatic cell counts leading to increased sodium and magnesium content (Hamed *et al.,* 2017). There were no significant differences ($p<0.005$) in the rating of appearance, flavor, mouthfeel, and smell among the treatments (Table 5.3). In appearance, milk from camels fed on CSC treatment was liked moderately (7.1) while milk from the camels which were only grazing was only liked (6.4). The appearance of camel milk scored higher (7.1) than all other attributes (4.9 to 5.6) as well as in comparison to cow and goat milk. It could be attributed to the opaque white color of camel milk which is due to the fact that fats are finely homogenized throughout the milk (Yadav *et al*., 2015). Also, it has the smallest fat globules (2.99 μm) compared to goat milk (3.19 μm)(Mansson, 2008). In flavor, goat milk (6.4) and cow milk (5.8) were liked, camel milk from the grazed animals was disliked (4.9) while camel milk from those fed CSC, *O. stricta*, and *O. stricta* plus CSC was neither liked nor disliked (5.3; 5.3;5.4). Goat milk was the most liked in all attributes except appearance, followed by cow milk. Camel milk was neither liked nor disliked. However, milk from camels fed on *O. stricta* alone was the most liked (5.2 to 6.9) in all attributes in comparison to camel milk from other treatments. The camels fed on *O. stricta* only could have had enough water from *Opuntia stricta* during the trials, increasing the water content of the milk therefore reducing the salt content (El-zubeir, 2014; Shuiep *et al*., 2014).The salt content in camel milk depends on the forage consumed and availability and quality of drinking water (Farah & Fischer, 2004; Farah, 2017).

There were significant differences ($P<0.005$) in preference and overall acceptability of camel milk compared to goat milk. There were no significant differences in the preference of milk from camels fed on different treatments. On overall acceptability, there was a significant difference ($p<0.005$) in milk from camels fed on *O. stricta* and CSC compared to that of camels fed other diets. The smell, taste, and salt content are affected by the type of forage as well as the availability of water (El-zubeir, 2014; Shuiep *et al*., 2014). However, there were no significant differences ($p>0.005$) between cow milk, goat milk, and camel milk of camels fed *O. stricta* and

CSC in overall acceptability. This showed that milk from camels fed *O. stricta* and CSC was acceptable by the consumers. The low overall acceptability of camel milk observed in the present study was in line with earlier reports on camel milk (Hashim 2002; Rahman *et al.,* 2009; Mohamed, 2011).

5.5 Conclusions

- The highest daily camel milk consumption was by panelists from camel keeping counties. Most panelists from non-camel keeping counties had never tasted the camel milk and a few consumed once in a month.

- Below 35 years, both female and male had equal frequency of daily camel milk consumption. Above 35 years, most females reported that they consumed camel milk daily while men consumed weekly.

- Camel milk was least favorable compared with cow milk and goat milk for all sensory attributes. Goat milk had the highest rating in all attributes evaluated followed by cow milk.

- Dietary treatments did not significantly ($P > 0.05$) affect the sensory characteristics of camel milk. Milk from camels supplemented with cotton seed cake alone had the highest score for appearance and preferences but the effects were not significant.

5.6 Recommendation

There is a need for further research to improve the sensory quality and acceptability of camel milk.

CHAPTER 6

6 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 General discussion

During drought animals die in large numbers due to depletion of pasture with cattle and sheep being the first to succumb, followed by goats. The most resilient are the camels that can survive for up to 14 days without water, whereas cattle and sheep only survive a few days. Unlike cattle and smaller livestock, Camels can utilize grass that has withered, such as Thorn bushes. One of the challenges experienced in camel rearing is fodder shortage especially during periods of prolonged drought.

Opuntia is regarded as an invasive species in ASAL regions in Kenya where most camels are kept in Kenyan. *Opuntia* is drought-resilient, tolerate severe utilization and provide large quantities of succulent fodder to camels during prolonged drought. The utilization of *Opuntia stricta* is much higher in camels than in any other animal.

During the wet season, the preferred species included; Acacia nubica, Acacia seyal, Cucumis aculeatus, Euclea divinorum, Hibiscus parrifolia. During the dry season, the most preferred species were; Barleria acanthoides, Balanites aegyptiaca, Cynodon dactylon, Lycium europaeum, Pollichia campestris. It was noted that the preferred forage species had high in vitro dry matter digestibility, low in fibre and ash but high in crude protein making them more palatable. Young cactus pear cladodes were nutritionally superior to the more mature ones. Young cladodes had lower fiber fractions than mature cladodes.

There was no significant difference in the dry matter intake among the treatments. The cotton seed cake was high in dry matter (88%DM) while the dry matter in *O. stricta* was low. Therefore, irrespective of high *O. stricta* intake on “as is” basis, the DM intake was still low and close to that of CSC. However, camels fed on *O. stricta* plus CSC treatment had the highest DM intake as it was the most preferred among the supplemental diets. The crude protein intake in the supplemental diets was significantly different among treatments. Although, it still showed an insignificant difference in the milk protein content and milk yield. There was no significant difference in milk yield and composition. Despite the fact that milk yield was not significantly affected by treatments, there was an increase in milk yield in all the treatments.

In sensory evaluation, camel milk had the lowest rating compared with cow milk and goat milk for all sensory attributes. However, for appearance, the camel milk was the most preferred in all attributes (7.1).

6.2 General conclusions

- The highest ranked forages were relatively higher in crude protein, calcium, ash, *in vitro* dry matter digestibility and lower in neutral detergent fiber concentrations, indicating that forage nutritive value affected the forage preference by the camels.
- The nutritional quality of *Opuntia stricta* cladodes was affected by stage of growth with young cladodes being more nutritious compared with mature ones.
- Digestibility of both young and mature cladodes of *Opuntia stricta* relatively high but they were low in dry matter and protein contents.
- Supplementation of grazing lactating camels did not have a significant effect on the camel milk yield but there was a trend where camels supplemented with *Opuntia* and CSC had the higher yields followed by those supplemented with cotton seed cake.
- The highest daily camel milk consumption was by respondents from camel keeping counties. Most respondents from counties that did not keep camels had never tasted camel milk and a few consumed once in a month.
- Camel milk had the lowest rating compared with cow milk and goat milk for all sensory attributes.
- Goat milk was more acceptable while camel milk from camels fed on *Opuntia stricta* was the least accepted.

6.3 General recommendations

- Interventions are needed to support and enhance the development of supplementation of grazing lactating camels with *Opuntia stricta* in ASALS.
- Appropriate and affordable camel supplementary feeding interventions, to mitigate feed shortage in dry and drought periods, would help support milk yield.
- Further research should be done on optimal level of *Opuntia stricta* supplementation to grazing lactating camels.
- There is a need for further research to improve the sensory quality of camel milk.

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APPENDICES

Appendix 1: Questionnaire for Sensory Evaluation

Consent form

Sensory evaluation of camel's milk

You are invited to participate in a research study of perception of camel's milk. I request that you read this form and ask any question that you may have before agreeing to be in the study.

This is a voluntary exercise to determine consumption of camel's milk.

Please do not participate in the study if you are allergic to milk.

The results of your performance as a panelist will be kept strictly confidential.

Kindly fill in your details in the section below

Gender

Male ☐ Female ☐

AGE:

Less or equal to 35 ☐ 35 and above ☐

How often do you consume camel's milk?

Daily ☐ Weekly ☐ Monthly ☐ Never ☐

B) STATEMENT OF CONSENT

I have read the information about the conditions of this sensory evaluation and all my concerns about the study have been addressed. I hereby give my voluntary consent for participation in this study.

Name: ___________________________________ Date: __ __ 2019

Signature: ______________________________

C) SENSORY EVALUATION QUESTIONNAIRE

Sub County: ________

Instructions

You have been provided with ten coded samples of boiled camel's milk.

Please take a sip of water to clean your palate before and after tasting the sample.

Taste the milk and hold in the mouth for at least 5 seconds before swallowing.

Record your perception in the scale below by ticking in the box against each statement. Please look and taste each of the four coded milk samples. Indicate how much you like or dislike each sample by checking the appropriate sample attribute and indicate your reference (1-9) in the column against each attribute. Put the appropriate number against each attribute

9- Like extremely

8 -Like very much

7- Like moderately

6- Like

5- Neither like nor dislike

4- Dislike

3- Dislike moderately

2- Dislike very much

1-Dislike extremely

Attributes	Sample codes									
	A	B	C	D	E	F	G	H	I	J
Appearance (color)										
Flavor (taste)										
Smell (aroma)										
Mouth feel										
Overall acceptability										
Would you prefer to buy?	Yes/ No	Yes/ No	Yes/ No	Yes/ No	Yes/ No	Yes/ No	Yes/ No	Yes/ No	Yes/ No	Yes/ No

Additional comments:

……………………………………………………………………………………………………

……………………………………………………………………………………

Thank you for participating in the study.

Appendix 2: Analysis of variance for Milk yield of lactating camels

Variate	Source of variation	d.f.	s.s.	m.s.	v.r.	P-value
MV(liters)	Treatments	3	2.385	0.795	0.44	0.566
	Residual	124	222.935	1.798		
	Total	127	225.319			
MD (kg/L)	Treatments	3	0.006897	0.002299	3	0.876
	Residual	92	0.070496	0.000766		
	Total	95	0.077393			