Sudan University of Science &Technology

College of Graduate Studies

Measurements of Milk Flow and Udder Morphology and Their Impact on Milkability and Selecting of Dairy Camel's (Camelus dromedarius) Under Intensive System

قياسات تدفق الحليب وشكل الضرع وأثرهما علي إمكانية الحلب لإختيار النوق الحلابة (ذات السنام الواحد) تحت النظام المكثف

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بسم الله الرحمن الرحيم

وَإِنَّ لَكُمْ فِي الْأَنْعَامِ لَعِبْرَةً ۖ نُّسْقِيكُم مِّمَّا فِي بُطُونِهِ مِن بَيْنِ فَرْثٍ وَدَمٍ لَّبَنًا خَالِصًا سَائِغًا لِّلشَّارِبِينَ

الاية (٦٦) سورة النحل

(And indeed, for you in grazing livestock is a lesson. We give you drink from what is in their bellies - between excretion and blood - pure milk, palatable to drinkers).

Al-Nahl (66).

Dedication

This work is dedicated to my dear family, my Father, my beloved mother, and my brothers and sisters, to my wife, daughters and my son for their support and sacrifice throughout my academic study.

With love and respect

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Abstract

This study is composed of two experiments the first experiment aims to study milking traits and milk flow parameters during lactation and their relationship with milk yield in 22 multiparous dromedary camels machine milked twice a day. A total of 921 milk curves were recorded throughout the lactation period using a two electronic milk flow meters (Lactocorder©). Results revealed that within 43 weeks of lactation average daily milk yield was 5.57 ±2.6 l. The peak milk yield was reached at the 26th week of lactation with 8.66 l and decreased thereafter with high lactation persistency (90.7%). Machine Milk (MM), machine stripping milk (MSM), average milk flow rate (AFR) and peak milk flow rate (PFR) were 3±1.67 kg /milking, 0.136±0.01 kg, 1.11 kg/min and 1.99 kg/ min respectively. Average durations of main milking phase, ascending phase, plateau phase, descending phase and total milking were 2.79 ± 0.05 min, 1.92 ± 0.05 min, 0.39 ± 0.02 min, 0.93 ± 0.63 min, 6.59 ± 0.09 min respectively. Stage of lactation affected positively peak and average milk flow rate and milking yield per milking. Lowest milk yield per milking, stripping milk, peak and average milk flow were detected at early stage of lactation. Significant (P<0.0001) longest duration of total milking was observed at late stage of lactation. Milk yield, duration of total milk yield per milking and duration of main phase for 14 hours milking interval “morning milking” was significantly (P<0.0001) higher comparing with 10 hours milking interval “evening milking”. Bimodality represented 29.3% of the total curves but this type was more common at mid stage of lactation (33%). Also, a higher total milk yield with the increasing of main and descending phase of milking were observed in this milk flow curve. Negative correlation occurred between average and peak milk flow and the duration of certain (main, plateau

and ascending) milking phase. Milk yield positively related to peak milk flow, average milk flow rate and duration of total milking time. Bimodality was positively correlated with milk yield, duration of main phase and descending phase.

The second experiment aims to study the change of udder morphology traits after a machine milking and the change of udder traits during stage of lactation. Moreover, to evaluate udder and teat shape in relation with milk yield. To determine udder and teats measurements which were taken directly before and after milking a total of 77 multiparous dromedary camels were used. On average the length, height, depth and circumference of the udder were 43.6±4.9, 106.9±7.7, 43.8±4.6, 97.1±6.3 cm respectively. The teat length front and rear, diameter and distance between teats were 4.85±1.85, 5.09±1.85, 3.43±1.05, 8.92±1.92 cm respectively before milking. Udder length and height did not change before and after milking while udder depth and circumference showed significant ($p< 0.00l$) decrease after milking. Front teat length significantly increased after milking while, teat diameter and distance between teats showed significantly decreased. Udder depth, udder circumference and distance between teats positively correlated with milk yield and affected significantly ($p<0.05$) by stage of lactation and showed highest value at mid stage of lactation: 46.1±4.2, 99.9±5.3, 9.6±1.8 respectively. Total milk yield reaches the highest value at mid stage of lactation. Seventy two lactating camels from experimental camels were classified for udder and teat shape. Udders were classified to: pear, globular and pendulous. While, teat were classified to: funnel, cylindrical and bottle shape. Globular shape at first and late stage was very common followed by pendulous and pear shapes. Cylindrical teats were more frequent followed by funnel and bottle shaped at

the first and late stages. A significant ($p \leq 0.05$) difference was observed in total milk yield according to udder shape at first stage of lactation. Highest milk yield of 5.64 kg was obtained from pear udder shaped followed by globular 4.7±0.28kg and pendulous 4.41±0.036 kg. Significant difference in length observed between pear against globular and pendulous. Teat length of front and rear, diameter and distance between teats were significantly ($p \leq 0.05$) lower in globular shaped from other shapes at first stage. We can conclude that stage of lactation, milking intervals and bimodality influence milking traits and milk flow parameters in dairy camels. Udder and teats measurement changes during milking and stage of lactation increase understanding for selecting lactating camels and improving camel machine milking efficiency. The study showed clear variation in the udder and teat shapes and dimensions and their relationship with milk yield in lactating camels.

الملخص

تشتمل الدراسة علي تجربتين ، التجربة الأولي وتهدف إلي دراسة صفات الحلب وقياسات تدفق اللبن خلال مرحلة الإدرار وعلاقتها بكمية إنتاج اللبن في عدد ٢٢ناقة متعددة الولدات تحلب آليا مرتين باليوم . سجل عدد ٩٢١ منحني لتدفق اللبن خلال موسم الإدرار بواسطة جهاز قياس تدفق اللبن الإلكتروني . من خلال ٤٣ إسبوعا من الإدرار أظهرت النتائج أن متوسط الإنتاج اليومي للبن ٥،٥٧ ±٢،٦١ لترا . وصل أعلي معدل لإنتاج اللبن في الإسبوع ال ٢٦ من فترة الإدرار وسجل ٨،٦٦ لترا ومن ثم إنخفض بنسبة مثابرة حلب تساوي ٩٠،٧%. حليب الماكينة ، حليب التقطير، ومتوسط معدل تدفق اللبن ، وأعلي معدل لتدفق للبن تساوي ٣±١،٦٧ كجم/ للحلبة ،٠،١٣٦±٠،٠١ جم ، ١،١١كجم /للدقيقة ١،٩٩ كجم /الدقيقة علي التوالي. متوسط الزمن لمرحلة الحلب الرئيسية ، المرحلة التصاعدية، مرحلة القمة ، المرحلة التنازلية ومرحلة الحلب الكلية يساوي ٢،٧٩±٠،٠٥ دقيقة ، ١،٩٢±٠،٠٥ دقيقة،٠،٣٩±٠،٠٢ دقيقة ،٠،٩٣±٠،٦٣ دقيقة ٦،٥٩±٠،٠٩ دقيقة علي التوالي . من جهة أخري أثرت مرحلة الإدرار إيجابيا علي متوسط معدل تدفق اللبن وأعلي معدل لتدفق اللبن وكمية إنتاج اللبن للحلبة الواحدة . كما أظهرت الدراسة بأن أقل قيم لكمية اللبن في الحلبة، حليب التقطير ، متوسط تدفق اللبن و أعلي معدل لتدفق اللبن كانت في المرحلة الأولي من الإدرار. سجل زمن الحلب الكلي أعلي معدلا معنويا ($p< 0.0001$) خلال مرحلة الإدرار الأخيرة. كما سجل إنتاج اللبن و زمن إنتاج اللبن الكلي وزمن فترة الحلب الرئيسية معنويا ($p< 0.000l$) أعلي معدلا عند الفترة بين الحلبتين ١٤ ساعة (الحلبة الصباحية) عند مقارنتها ب ١٠ ساعات للفترة بين الحلبيتن (الحلبة المسائية). أعطي الشكل الثنائي لمنحني تدفق اللبن نسبة ٢٩،٣ % من بين جملة مجموع منحنيات تدفق اللبن وكان سائدا أكثر خلال مرحلة الإدرار الوسطي بنسبة ٣٣%. أيضا تلاحظ أن إنتاج اللبن الكلي وزمن الحلب الرئيسي وزمن المرحلة التنازلية هي الأعلي في منحنيات تدفق اللبن الثنائية. لوحظ أن هنالك إرتباطا سالبا بين متوسط معدل تدفق اللبن وأعلي معدل لتدفق اللبن من ناحية و زمن الحلب للفترة (الرئيسية ، قمة الحليب والفترة التصاعدية). إرتبط إنتاج اللبن بصورة إيجابية بكل من متوسط تدفق اللبن ، أعلي معدل لتدفق اللبن وزمن الحلب الكلي . المنحني الثنائي لإنتاج اللبن يرتبط إيجابا بإنتاج اللبن وزمن الحلب التنازلي و الزمن الرئيسي لانتاج الحليب .

في التجربة الثانية من الدراسة أستخدم عدد ٧٧ ناقة لدراسة التغير في شكل الضرع بعد الحلب و التغير في صفات الضرع خلال مرحلة الإدرار. إضافة الي دراسة و تقييم شكل الضرع والحلمات وعلاقتها بإنتاج اللبن . أجريت قياسات الضرع والحلمات مباشرة قبل وبعد الحلب الآلي . متوسط طول ، إرتفاع ، عمق و محيط الضرع يساوي ٤٣،٦±٤،٩ ، ١٠٦،٩±٧،٧ ، ٤٣،٨±٤،٦ ، ٩٧،١±٦،٣ سم علي التوالي. طول الحلمة الأمامي والخلفي ، قطر الحلمة والمسافة بين الحلمات تساوي ٤،٨٥±١،٨٥، ٥،٠٩±١،٨٥، ٣،٤٣±١،٠٥، ٨،٩٢±١،٩٢ سم قبل الحلب علي التوالي . قيم طول وإرتفاع الضرع لم يظهرا تغيرا قبل وبعد الحلب بينما أظهرت قيم عمق ومحيط الضرع إنخفاضا معنويا ($p< 0.001$) بعد الحلب الآلي . من ناحية أخري تلاحظ إختلافا معنويا عاليا بين طول الحلمة الأمامية ، قطر الحلمة والمسافة بين الحلمتين قبل وبعد الحلب. طول الحلمة الأمامية إزداد بصورة معنوية بينما أظهر قطر الحلمة والمسافة بين الحلمات إنخفاضا معنويا . كما أظهرت الدراسة أيضا إرتباطا بين عمق ومحيط الضرع والمسافة بين الحلمات وإنتاج الحليب و تأثروا معنويا ($p< 0.05$) بمرحلة الإدرار وأظهروا أعلي معدلا خلال مرحلة الإدرار الوسطى : ٤٦،١±٤،٢، ٩٩،٩±٥،٣ و ٩،٦±١،٨ على التوالي. وصل متوسط كمية الحليب الكلي اعلي قيمة له عند فترة الحلب الوسطى.

لتصنيف شكل الضرع والحلمات أستحدمت عدد ٧٢ ناقة حلابة من نياق التجربة . قسم شكل الضرع الي : كمثري، كروي وضرع متدلي . بينما صنفت الحلمات الي : قمعية ، أسطوانية وقنينية الشكل. شكل الضرع الكروي هو السائد في مرحلة الإدرار الأولي والأخيرة ومن بعده الشكل المتدلي والشكل الكمثري . شكل الحلمات الأكثرا إنتشارا هو الشكل الأسطواني ومن بعدها الحلمات القمعية ومن ثم الشكل القنيني. لوحظ اختلافا معنويا ($p<0.05$) لكمية الحليب الكلي بناءا علي شكل الضرع في مرحلة الإدرار الأولي. بواسطة مقياس أسطواني متدرج سجل أعلي متوسط لإنتاج الحليب ب٥،٦٤ كجم من الضرع الكمثري الشكل ومن بعده ٤،٧±٠،٢٨ كجم من الضرع الكروي ومن ثم ٤،٤١±٠،٠٣٦ كجم من شكل الضرع المتدلي، كما لاتوجد فروقات معنوية لشكل الحلمات وكمية إنتاج الحليب. تلاحظ إختلافا معنويا ($p<0.05$) لطول الضرع بين الشكل الكمثري ضد الشكل الكروي والمتدلي. أظهر قياس طول الحلمة الأمامية والخلفية ، قطر الحلمة والمسافة بين الحلمات إنخفاضا معنويا لشكل الضرع الكروي مقارنة ببقية الأشكال خلال مرحلة الإدرار الأولي. في الختام يمكننا القول علي أن هناك أثرا واضحا لمرحلة الإدرار والفترة بين الحلبتين ومنحني اللبن الثنائي علي إنتاج اللبن وقياسات تدفق الحليب. تغير قياسات الضرع والحلمات خلال الحلب وخلال مرحلة

الإدرار يوسع مداركنا لإختيار الإبل الحلابة وتطوير ماكينة الحلب الآلي وزيادة كفاءتها. كما أظهرت الدراسة تباينا واسعا في شكل الضرع والحلمات وقياساتهما وكذلك علاقتهما بإنتاج الحليب في الإبل الحلابة.

Chapter One
Introduction

CHAPTER One
Introduction

Camel milk is the sole nourishment for camel pastoralists for prolonged periods each year. The camel proved that it is the fit domestic animal during severe drought periods. Camel milk dairies have come up as business activity in most camel possessing nations. As such, the market potential for camel milk could be highly developed in the future (Faye *et al*., 2014).

Improvement of machine milking for dromedaries is still at early stage and requires further research to define factors affecting and improving milk ejection (Nagy *et al*., 2015; Ayadi *et al.,* 2016). Milk flow measurement equipment's give a unique potential to investigate milk flow curve of lactating camels. Recording of milk flow is used for evaluation and development of milking machine and in setting of the milking machine to get sufficient results (Thomas *et al.,* 1991; Rasmussen, 1993). The shape and the parameters of milk flow depends on various factors such as teats anatomy, parity and stage of lactation. Moreover, milking conditions (i.e. machine characteristics, milking routine and milking intervals) affected milk flow curve parameters (*Sandrucci et al*., 2007). Furthermore, duration of udder stimulation affected milk flow traits and milk partitioning in the udder of dairy camels (Ayadi *et al.,* 2016). However, few data are available in the literature about the change of milk flow traits throughout lactation in dairy camels under intensive production system.

The udder is a very important organ of the dairy animal and its physiological and conformational characteristics are linked to their dairy performance (Kominakis *et al.,* 2009). The udder dimensions and morphology were added in selection programs of ewe (De la Fuente, 1996), buffalo (Prasad *et al.,* 2010) and cow (Seykora and McDaniel, 1985). In general appearance, lactating camels are characterized by well–developed udder and prominent milk vein (Al-Ani 2004). Camel udder morphometric proved to have an impact on milk yield, and the morphologic change before and after hand milking may indicate potential in milk secretion under extensive production system (Eisa *et al* 2010). However, few studies investigated the change of udder morphology in dairy camels after machine milking (Ayadi *et al.,* 2015; Nagy *et al.*, 2015). Udder morphology has been recognized as one of the main factors affecting the ability of machine milking of dairy camels (Shehadeh and Abdul-Aziz, 2014; Caja *et al*., 2011). External udder measurements could give us an idea about the storage capacity of the udder and may offer first elements that could be used as additional parameters. Moreover, the evaluation of udder morphology during lactation can be significant for obtaining a positive genetic response in the milkability of dairy camel (Atigui *et al.,* 2016; Ayadi *et al.*, 2013).

The conformation of udder and teats is one of the key points in the evaluation of lactating camels; udder and teats shape described essential and assistant steps of the development of machine milking in camels (Marnet *et al.,* 2016), good homogenous udder morphology is desirable for good milkability. In this context, the typology of the udder and teat reverse that camels need special milking clusters to improve milkability (Ayadi *et al*., 2016). Milk yield and milking time varied among udders and teats shape in dairy cows (Tilki *et al.,* 2005a). Otherwise the association of common udder infections with udder shape was studied (Bhutto *et al.,* 2010) in cows. Udder characteristics need to be included in breeding programs in dairy camel, beside milk production and quality traits. The most important traits of udder are known as shape, size and placement of udder and teats attachment.

The objectives of the study were:

1. General objectives:

1. To evaluate milk flow traits, change of udder morphology traits after a machine milking during lactation and to determine suitable udder and teat shape for lactating camels.

2. Specific objectives:

1. To compare milk flow traits during lactation and to estimate their relationships with milk yield in morning and evening milking session.
2. To study the change in udder traits throughout lactation, and its relationship with milk yield in dairy dromedary camel maintained under intensive condition.
3. To provide basic information on milk flow traits, udder and teats measurements and shape for further studies on its association with milking machine efficiency, udder health, camel breeds and selection programs.

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Chapter Two
Literature Review

CHAPTER TWO

Literature Review

2.1 Domestication and classifications of camels

The dromedary camel (*Camelus dromedarius*) is of great importance to nomadic and rural communities mainly in the dry tropics of Africa and Middle East. Camels gained immense importance as sustainable livestock species for their specific features (e.g., immunogens and milk composition (Burger, 2016). Camels have inherited the main target as sustainable livestock species, distinctive in their morphological and physiological characteristics and capable of providing vital products even under extreme environmental conditions.

According to Yam *et al.,* (2015) the evolutionary history of dromedary and Bactrian camels traces back to the middle Eocene (around 40 - 50million years ago), when land masses were still joined and the ancestors of Camels emerged on the North American.

The Camelides belong to order Artiodactyla and suborder Tylopoda. The Old World camelids can be divided into two forms: one-humped and two-humped camels. Traditionally, they have been considered different species, named dromedary or Arabian camel (*Camelus dromedarius* Linnaeus, 1758), and Bactrian or Asian camel (*Camelus bactrianus* Linnaeus, 1758). The new world camels (genus Lama with the species *L. glama, L. guanicoe*, *L. pacos* and genus Vicugna with the species *V. vicugna*).

The new classification system of camel based on the camel performance as Meat, Dairy, Dual purpose and Race animals. Such system of classification will fit the requirements for the development of camel production and the improvement of the standard of their herders (Wardeh, 2004)

2.2 Camel populations and distribution:

The camel plays vital socio-economic roles and supports the survival of millions of people in the semi dry and arid zones of Asia and Africa. As estimation of Food and Agriculture Organization the total population of camel in the world is believed to be 28,811,392 million (FAOSTA, 2016), of which 89% are one-humped dromedary camels (*Camelus dromedarius*) and the remaining 11% are the two-humped (*Camelus bactrianus*) that generally found in the cold deserts of Asia.

Wilson *et al.*, (2005) stated that, the dromedary camel is the most important livestock animal in the semiarid areas of Northern and Eastern Africa as well as in the Arabian Peninsula and Iran.

The habitat of the dromedary is the dry hot zones of North Africa, Ethiopia, the Near East and West Central Asia. Bactrian camel occupies the cold deserts of southern areas of the former Soviet Union, Mongolia, East-Central Asia and China (Wilson, 1984).

The most important countries for camel economy with a camel population over 1 million are in the order: Somalia, Sudan, Ethiopia, Niger, Mauritania, Chad, Kenya, Mali, and Pakistan (Faye. 2013).

(Massicot., (2006) stated that, the almost 14 million Dromedaries alive today are domesticated animals, which most living in Somalia, Sudan, Mauritania, and nearby countries. Otherwise, the Bactrian camel reduced to an estimated 1.4 million animals, mostly domesticated. Moreover, it is thought that there are about 1000 wild Bactrian camels in the Gobi Desert in China and Mongolia.

As reported by Saalfeld *et al.*, (2010), there is a substantial feral population (originally domesticated but now living wild) estimated at up to 700,000 in central parts of Australia, this population is growing at approximately 11 percent per year and in recent times the state government of South Australia has decided to cull the animals using aerial marksmen, because the camels use too much of the limited resources needed by sheep farmers.

In Saudi Arabia, the number of camels reported by (FAOSTAT, 2016) was about 260,000 head. Despite this large number, the camel milk production contributes about 4.5% of the total amount of milk produced annually from the different dairy species (FAOSTAT, 2014).

2.3 Nutritional and medicinal value of camel milk: -

2.3.1 physio-chemical properties of camel milk: -

Physio-chemical analysis is important tool to monitor the quality of dairy products. Measurement of physiochemical properties of milk is used to determine the concentration of milk component and to evaluate the quality of milk products. Gakkhar et al., (2015) compared various physiochemical properties of camel milk including its fat, total protein, freezing point with different species (table 2.1).

2.3.2 Nutritional value: -

The primary purpose of food including dairy and dairy products is to provide nutrients to fulfil the body's traditional requirements. Camel milk is generally described as opaque-white, frothy, sweet and sharp but sometimes salty in taste (Al haj and Al Kanhal, 2010).

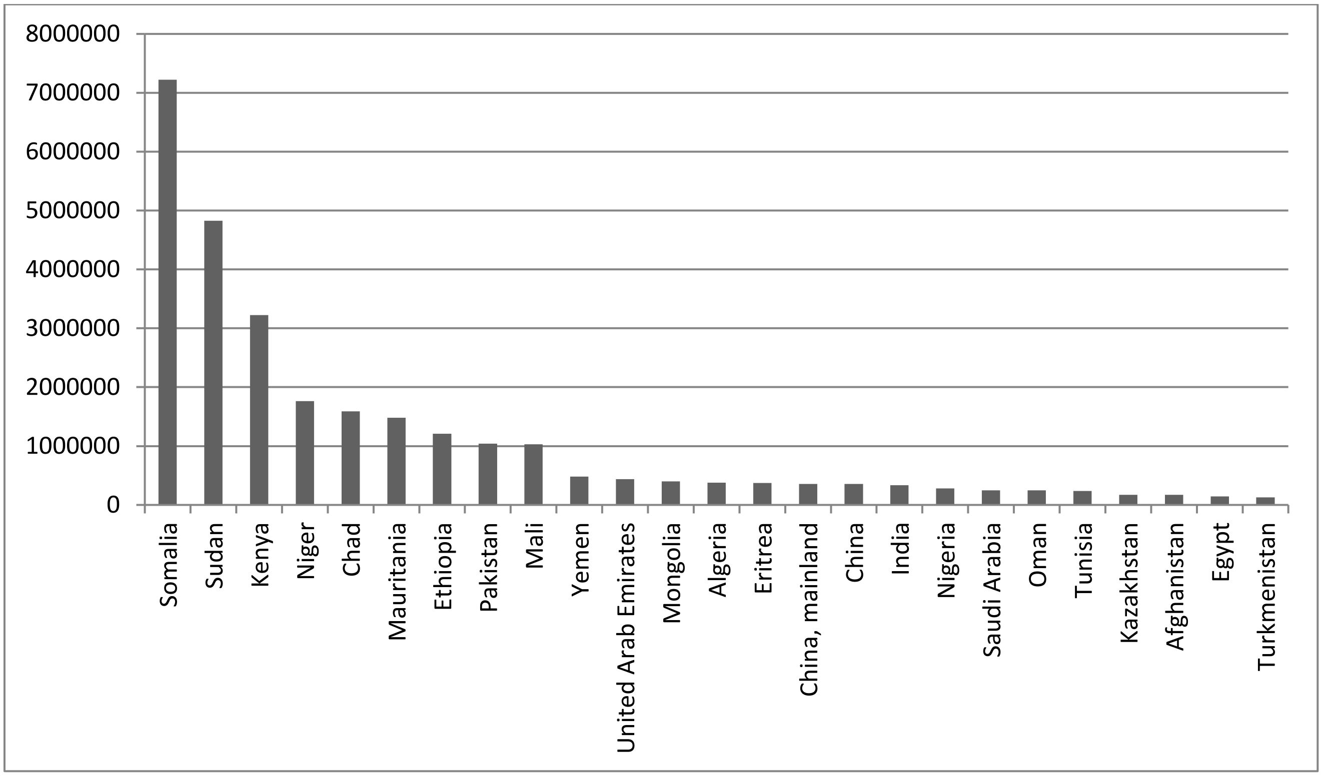


Fig 2.1: Top twenty - five countries around the world in terms of camel population according to FAOSTAT (2016).

Table 2.1: Physiochemical properties of camel's milk compared to some lactating animals

Milk sample	s. gravity	Freezing point c°	Lactic acid%	Color	Fat (mg/g)	Protein(mg/g)
Buffalo milk	1.032	-0.549	0.162	Creamy white	65.3	43.5
Camel milk	1.014	-0.535	0.216	White	36.1	30.2
Cow milk	1.030	-0.547	0.180	Yellowish white	41.5	32.3
Goat milk	1.028	-0.542	0.135	white	45.2	33.4

Source: Gakkhar *et al*. (2015).

Camel's milk is much more nutritious than that from a cow. It is lower in fat and lactose, and higher in potassium, iron and Vitamin C (Konuspayeva *et al.*, 2008).

Camel milk is enriched with all the health essential nutritional constituents found in bovine milk. The value of camel milk basically related to its chemical compositions (Mohamed and Larsson, 1990). Wide variation in constituents of camel milk is attributed to some factors such as parity, seasonal or physiological variations, water availability and physiological stage (*Musaad et al.*, 2013b).

Mal et al., (2006) recorded, camel milk fat ranges between 2.6% to 3.2%. Konuspayeva *et al.*, (2008) reported an average 3.82 g fat/100 ml in a meta-analysis of the literature data on the composition of milk from dromedary camels, Bactrian and hybrids.

Wernery (2007) reported that some unsaturated fatty acids are higher in camel than cattle, and lactose intolerance against camel milk does not exist.

Compared to cow, buffalo and ewe milk fat, camel milk fat contains fewer short-chained fatty acids, but the same long-chained fatty acids can be found.

Khan and Iqbal, (2001) evaluated camel milk composition and mentioned that, camel milk contains 2.9 to 5.5 % fat, 2.5 to 4.5% protein, 2.9 to 5.8% lactose, 0.35 to 0.90% ash, 86.3 to 88.5% water, and 8.9 to 14.3% Solid None Fat (SNF).

Camel milk contains two main fractions of proteins: casein and whey protein. The total amount of proteins varies from 2.15 to 4.90 % respectively, with average of 3.1 % (Konuspayeva *et al.*, 2008). Casein is the main camel milk protein and its share in the milk of one-humped camels is 1.63-2.76 %, which represents about 52- 87 % of total protein (Khaskheli *et al.*, 2005).

Moreover, Camel milk has a higher concentration of β-casein and lower concentrations of κ- and α-casein than cow milk. Caseins are easily digestible in the host intestine and are an excellent source of amino acids for growth and development of the young.

According to Haddadin *et al.*, (2008) the mineral content of camel milk varies from 0.82-0.85% and this Variations attributed to breed, differences feeding, analytical procedures and water intake.

Camel milk contains considerably less vitamin A and B2 than cow milk while the content of vitamin E was about the same level. In the other study Kheraskov, (1961) stated that, the level of vitamin C in camels milk was in average three times higher than that of cow milk and 10 times higher in iron. Furthermore, Sawaya *et al.*, (1984) studied the vitamin content of Saudi dromedaries and found mean values of 0.15, 0.42 and 24 mg/kg for vitamin A, B2 and C respectively.

Camel milk is low in lactose compared with cows' milk (Elamin and Wilcox, 1992). However, levels of potassium, magnesium, iron, copper, manganese, sodium and zinc are higher than in cows' milk (Sawaya *et al.* 1984; Abu-Lehia, 1987). In addition to the mention, Camel milk has a high biological value due to its high content of antimicrobial factors such as lysozme, lactose and immunoglobins (Elagamy, 1994).

2.3.3 Medicinal properties:

Camel milk not only provides the required nutrition for local people, but also offers several medicinal properties (Bai & Zhao, 2015). Wernery (2003) reported that recent data suggested that camel’s milk contained medicinal properties to treat different ailments such as Auto Immune Disease, Juvenile diabetes, booster of immune system, stress, peptic ulcers and skin cancer.

Camel milk and urine have been used as medicines in certain parts of Asia and Africa since ancient times, but only recently have scientists shown interest in exploring the claimed therapeutic benefits of camel products (Abdel Galil *and abdulgader*, 2016).

Camel milk is used therapeutically against dropsy, Jaundice, problems of the spleen, tuberculosis, asthma and anemia (Rao *et al.*, 1970). Camel milk was also reported to have other potential therapeutic properties, such as anti-carcinogenic (Magjeed, 2005), anti-diabetic (Agrawal *et al.*, 2007) and anti-hypertensive (Quan *et al*., 2008) and has been recommended to be consumed by children who are allergic to bovine milk (El-Agamy *et al.*, 2009).

Sharmanov *et al*., (1982) were the first to suggest an anti-viral action of camel milk when they recorded more effective than mare's milk in improving and normalizing the clinical and biochemical status of patients with chronic active hepatitis.

According to Kanwar *et al.*, (2015) camel milk is rich in lactoferrin with potent antimicrobial and anti-inflammatory properties. Similarly, Habib *et al*., (2013) reported that, camel milk lactoferrin seems to have great potential in practical medicine including bacterial inhibition, antiviral effects, antifungal effects, immune supportive and immunomodulation functions and anti-cancer actions.

The concentration of immunoglobulins in raw camel milk (2.23 mg/mL) is 4 to 6 times higher than in cow and buffalo milk, respectively, whereas the lactoferrin concentration (0.17 mg/mL) is 2 and 6 times higher than that of cow and buffalo milk, respectively. Similarly, the concentration of lysozyme (1.32 μg/mL) is 4.9 and 11 times higher than in cow and buffalo milk, respectively (El-Agamy, 2000).

2.4 Camel reproductive traits: -

In spite of the expansion of camel farming, the improvement of productivity was poor. Reproductive efficiency is the primary factor affecting productivity in the female camel, by the late attainment of puberty and the long calving interval. In Saudi Arabia Almutairi *et al*. (2010b) reported, in camel the age at first conception, age at first calving, open period, calving interval, gestation length and weight at calving of camels averaged 42.3 months, 54.8 months, 10.6 months, 22.6 months, 377.5 days and 591.9 kg, respectively.

In commercial ranches of Kenya, Wilson (1986) reported that the youngest age at first parturition was 45.6 months and the oldest age was 71.3 months. In Sudan, Musa *et al.*, (2006) reported that Arvana camels' early maturing reaches before the age of 3 years. Richard and Gerard (1989), stated that the days of open period in camels averaged 8 months. While, the calving interval ranged from 13 to 32 months. Under improved management, Bakkar and Basmaeil (1988) recorded a calving interval of 14.3 months in Najdi camels in Saudi Arabia.

Shorter gestation periods of 345–360 days were showed by Yagil and Etzion (1980). Kadim *et al.* (2008) reported, in their literature review, that the adult weight of camels varied from 450 to 700 kg. The heavy weight of camels may be due to the quality and quantity of feed provided in the centre.

In a wide study of Saudi camel Ali *et al*, (2018) stated that, the average of female breeding age, male breeding age, mating season, overall pregnancy rate, pregnancy duration, mating after calving, weaning age and calving interval was 4.2 ±0.06 years, 4.88 ±0.06, years ± 6.17 ±0.19 months, 82.64± 1.49(%), 12.29 ±0.04 months, 7.89 ±0.35 months, 8.96 ±0.22 months, 22.73± 0.47 months, respectively.

2.5 Camel production traits: -

2.5.1 Camel milk yield and lactation length: -

Camel milk is gaining more popularity, and several commercial farms are being developed to supply consumers with fresh milk. Camel can produce more milk for a longer period of time than any other domestic livestock species. The whole production of camel milk within 33 countries around the world was estimated to be 2,711,822 tones, with the highest production in Somalia, Kenya and Mali. Furthermore, the camels in Saudi Arabia produced about 76,000 metric tons of milk (FAOSTAT.2016).

Regarding camel milk yield Osman *et al.,* (2015) reported that, most of she-camels at Sudan - Gaderif State produced from 2 to 3 liters' milk/day in the pastures during the lactation period of 10 months with milking frequency ranged between 2 to 3 times in a day.

A study in South East of Algeria, Hadef *et al.*, (2018) revealed that the mean of camel milk yield was 3.96 ± 1.24 L/day with the length of lactation period estimated as long as nine months. Musaad *et al.,* (2013a) recorded 12.5 l as average months of lactation with the mean volume of 1,970± 790 l during lactation in Saudi Arabia intensive system.

In Tunisia El-Hatmi *et al.,* (2004) mention that, camel milk is considered a secondary product and reserved for calves and shepherds. Under these conditions, daily milk yield is 2.0 L on average.

In Sub-Sahara Africa Raymond., (1994) reported that lactation length of camel varies from one region to another from 8 to 24 months and milk production varies from 1500 to 12,775 kg, furthermore, milk production adjusted for a 305-day lactation ranges from 1000 to 10,600 kg, with the average daily milk yield for camels ranging from 1.5 to 8 kg.

AL-Shaikh *et al.*, (1994) recorded, an average of 10.23 kg per day in late lactation and milk yield of some individual females producing up to 18 kg per day in multiparous dromedary's camels in Saudi Arabia.

The mean daily milk production of 6.7 ±0.10 kg for 400 days with a range of 2.4-17.4 kg/day in the United Arab Emirates large scale company was reported by Nagy *et al.*, (2013a). Similarly, In Pakistan Raziq *et al.*, (2008) reported that, under good management conditions the milk yield varied from 15-20 kg/day during a lactation period of 8-18 months.

In recent years many practical efforts have been done and a reasonable population of high-yielding camels is placed in some countries with the modern camel dairies.

2.5.2 Lactation curve of camel:

The shape of lactation curve depends on the initial milk yield, peak yield, and persistency. Aziz *et al*., (2016) in Saudi camels reported that, Initial milk yield estimated by the linear and non-linear forms of the nine parities ranged between 0.194 and 1.775 and between 0.155 and 1.818, respectively. The increasing rate ranged between 0.754 and 1.414 and between 0.750 and 1.533, while the decreasing rate ranged between−0.054 and −0.020 and between −0.059 and −0.036, respectively.

According to Musaad *et al.* (2013a) the lactation curve based on monthly data, peak lactation started from the fifth month with the value of 220±90 l up to the eighth month with 220±67 l. Milk yield varied between 57±58 and 96±77 l at the first month and the end of lactation (15th month), respectively. The persistency after the peak of lactation was 95.9 %.

Table 2.2: Top ten camel milk producers' countries according to FAO statistics (2016).

Rank	Country	Production (tones)
1	Somalia	952,654
2	Kenya	848,939
3	Mali	271,614
4	Ethiopia	179,659
5	Niger	99,218
6	Saudi Arabia	76,056
7	Sudan	60,699
8	United Arab Emirates	52,582
9	Mauritania	26,098
10	Chad	22,849

Almutairi *et al.* (2010a) observed that daily milk yield of Saudi camels increased after parturition until reaching a peak at 95 and 155 days of lactation, and the persistency percentage reported in their study was 87.3%.

Shawket and Ibrahem (2012) observed that camel's fed Atriplex had a lactation curve with two peaks at fifth and seventh months of calving, whereas the lactation curve of camel group fed berseem hay had one peak occurred at the fourth month from calving.

In Tunisian camel Kamoun *et al.* (2012) found that, the peak production occurred approximately between 3rd to 4th months postpartum and then decreased. Similarly, Nagy *et al.* (2013b) reported that lactation curve reached its peak during the 4th month after parturition (8.9 kg), then it decreased gradually, falling to 50% of the maximum by the 16th month postpartum (4.3 kg).

Zayed *et al.* (2014) obtained higher values of peak yield than those reported in the present study, accounting for 77.6, 61.5 and 49.2 kg milk/week, but the weeks to attain peak production were lower, accounting for 7.71, 7.28 and 8.06 for Bushari, Arabi and Anafi camels, respectively.

Regarding the effects of parity on lactation curve Musaad *et al.* (2013a) announced that the eighth parity reached a peak earlier and had a higher production value at the peak with a lower persistency rate than at the sixth parity. All lactation curves increased regularly up to the production peak followed by a slightly sloping curve except at the first parity when production remained stable up to the ninth week.

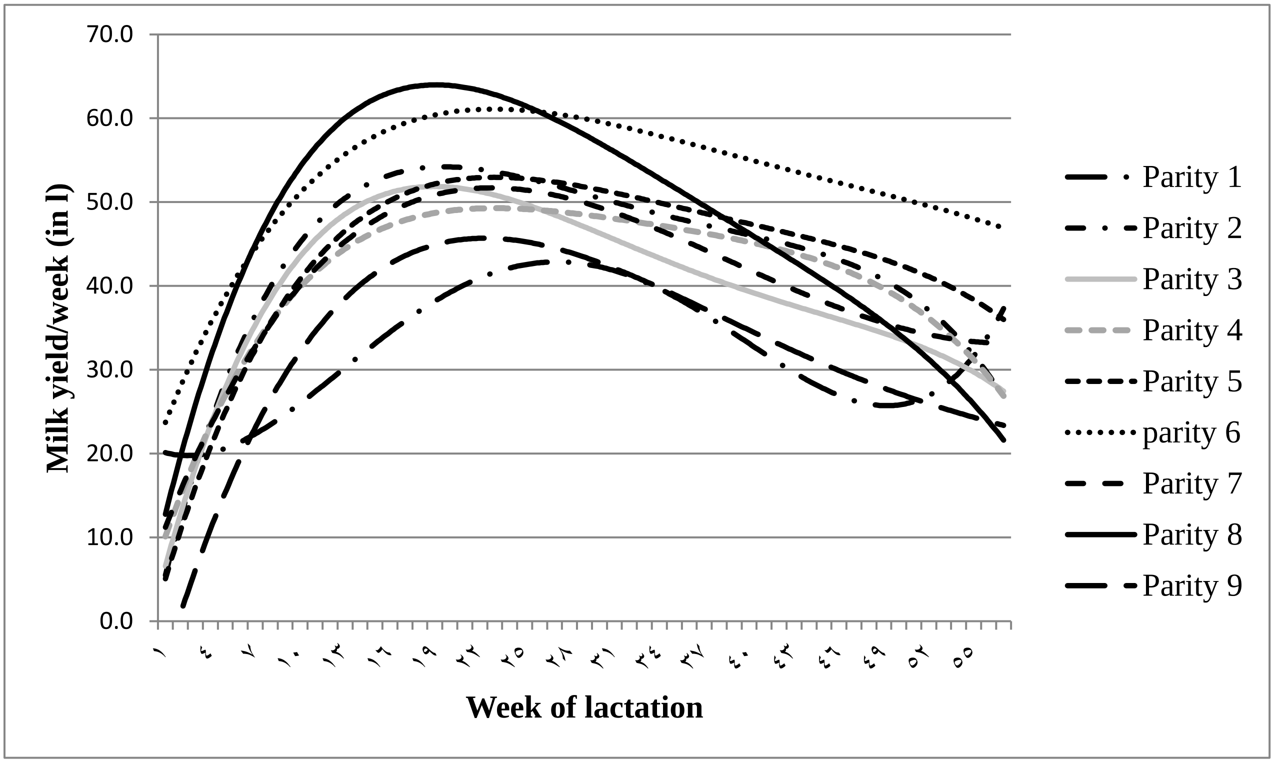


Figure 2.2 Camel lactation curves according to parity (n=72 lactations), (Musaad *et al.*, 2013a)

2.6 Factors affecting milk yield in camel:

2.6.1 Breed:

Milk yield varies with breed, stage of lactation and management conditions as for the other dairy animals. Dow elmadina *et al*. (2014) demonstrated, great impact of breed on milk yield of she camels reared within two different production systems in Sudan.

Basmaeil and Bakkar, (1987) recorded, milk yield of Majaheem camels for a period of 44 weeks ranged from 2.4 to 7.6 litres with the average milk yield of 5.5. ± 1.5 litres.

Milk yield of five Dankali camels kept on natural pastures in Ethiopia was recorded over a period of 12 months recorded the mean yield per head of 12, 3 litres according to Richard and Gerard, (1989).

A study on nine Magrebi camels showed that in 305 days their milk yield varied from 915 to 3900 litres (Kamoun *et al.,* 1990). In addition, Schwartz (l992) reported that, heavy camels of Pakistan and India may produce up to 12,000 litres milk in a lactation ranging from 9 to 18 months.

2.6.2 Stage of lactation:

Many factors affect camel milk yield such as genetic origin, environmental conditions, feeding management conditions, Number of lactations and stage of lactation (Musaad *et al*. 2013a; Al haj *at el.* 2010).

Aziz *et al.*, (2016) in Saudi camels found that averages of total milk yield, lactation length and daily milk yield of the nine parities, ranged between 967.3 and 3107.21 kg, between 273 and 416 days and between 2.96 and 7.40 kg/day, respectively.

Babiker *et al.*, (2014) in intensive farming system reported that, the highest milk yield for camels at first three months of lactation (2.96±1.28 L) and the lower milk yield was found for camels at late lactation (2.11±0.99 L).

Hadef *et al.*, (2018) stated, the milk yield was significantly higher during the mid-stage (4.78 ± 1.13 l/d) as compared to those obtained for the early (3.58 ± 1.18 l/d) and late stage (3.52 ± 0.99 l/d) of lactation in South East of Algeria semi intensive camel farming system.

2.6.3 Parity:

Al- Saiady *et al.*, (2012) studded some factors affecting milk yields in Saudi Arabia camels they reported that, the lowest milk yield was at the 1st, 2nd, and 4th parity.

On the another study in Pakistan camel by Razig *et al.*, (2011) they postulated that, the highest milk yield (3168 kg) in the Kohi dromedary camel was demonstrated in the 5th parity (13.5 years), followed by 3051 kg in the 3rd parity (8.8 years) and 3010 kg in the 4th parity (11.5 years). However, the lowest milk yield (1566 kg) was produced in the 1st parity (4.5 years).

Babekir *et al.*, (2014) stated that, She-camels in the second parity gave the highest milk yield (4.06±1.85 L/day) with lower milk yield at the subsequent parities.

Musaad *et al.*, (2013a) showed that, the highest average yield recorded in Saudi Arabia was for camels at sixth parity, whereas the highest weekly peak was at eighth parity, and highest persistency at fifth parity.

Zeleke (2007) recorded that, the lowest milk yield in camels at the sixth parity and the highest at the third. While, Bekele *et al.* (2002) reported the highest daily milk off-take between the third and fifth parities, and the lowest at the first parity and after the seventh.

In Pakistan Raziq *et al.*, (2011) investigated the highest milk production at the fifth and also mentioned a significant difference between the first parity and all the other parities.

2.6.4 Season:

Seasonal changes in temperature, water availability and feed quality affected camel milk yield as well the composition of camels' milk (Musaad *et al*., 2013b)

Bekele *et al.*, (2002) reported that, camels that calved during the long dry season had longer lactation period (409±32 days) while camels that calved in the short rainy season (March–April) or in the short dry season (May–June) had a shorter lactation period (292±51 and 287±31 days, respectively).

In intensive farming system, Musaad *et al*. (2013a) revealed that the highest milk production in June, July, and August. Moreover, Camels calving in winter had longer lactation length and high persistency and higher peak yield, whereas camels that calved in summer had shorter lactation with an early peak in production.

2.6.5 Nutrition:

Variability in the production and composition of camel milk, originating mainly from animals feeding (Khan and Iqbal, 2001; Konuspayeva et al., 2008; Musaad et al., 2013b). At the same time, the traditional system tending to be progressively replaced by a more modern system based on intensive feeding of cultivated fodder in order to increase dairy production. Bekele et al. (2002) concluded that if camel had been kept under better management conditions milk production would be better.

Schwartz., (l992) reported that the yield of Somalian and Kenyan dromedaries ranges from 1,300 to 2,500 litres, but with good grazing their yield may even exceed 3,000 litres.

Milk production could be optimized by a better energy supply rather than protein, the high capacity of camel to recycle urea is obviously an advantage (Al-Saiady et al., 2012).

2.6.6 Environment:

Camels live in habitat with high temperature differences and scarce precipitation. In the course of evolution, camels have adapted to conditions of such environment.

Identification of environmental factors that affect milk production potential of camels and the quality of their milk is crucial for designing improvement measures and thereby improve the living standard of pastoralists (Zeleke, 2007).

EI-Badawi., (1996) reported that dams maintained on irrigated pasture could yield 15 to 35 litres milk/head per day, while the yield was 3 to 5 litres per day on desert range.

Yagil and Etzion, (I980) determined the camel milk yield in hot summer and stated that the camels subjected to water restriction once per week for two hours produced a steady amount of 6 litres per day/camel.

2.7 Camel milk products:

Most camel milk is consumed fresh or when just soured. Kalla *et al.,* (2017) reported that, differences between camel and bovine milk composition had routed to some difficulties in manufacturing derived dairy product. Despite of difficulties many camel milk products have been developed throughout the world. New technologies were introduced to produce high quality camel's milk products (Wernery, 2007).

2.7.1. Pasteurized camel milk:

Pasteurized milk and other dairy products made from camel's milk are available in the markets in Gulf area and Mauritania (El-Agamy, 2000).

Camel milk is more heat resistant than those in cow milk, which is advantageous in commercial production of camel milk products (Wernery, 2003). Moreover, camel milk antimicrobial factors were significantly more heat resistant than cow and buffalo milk.

Hassan *et al.*, (2006) found pasteurization of camel milk before its fermentation into Gariss improved the microbiological content and increasing the shelf life of the product. Moreover, the heat treatment improves the microbial quality and extends the shelf life of camel milk Mohamed *et al*., (2014).

Tay and Chua., (2006) stated that, camel milk pasteurized with High Temperature Short Time (HTST), where the raw camel milk will be indirectly heated to 72C^{o} for 15s via a heat exchanger, ready for consumption or can be refrigerated and stored for up to 21 days.

2.7.2 Yogurt:

Mortada *et al.*, (2013) checked the possibility of yogurt manufacturing from camel milk and reported that, yoghurt made from camel's milk revealed a longer shelf life than any other milk.

Al-Nabulsi *et al.*, (2016) reported that, appropriate care should be taken during production of yogurt from camel milk to minimize the potential for post process contamination by some foodborne pathogens.

2.7.3 Fermented camel milk:

Elagab and Elfaki, (2002) defined, "Garis" as a special kind of fermented camel milk products in Sudan. In the same way, Seifu (2007) mentioned that, Camel herders in Ethiopia make fermented sour milk called "dhanaan*"* traditional product from camel milk.

Konuspayeva *et al.*, (2007) stated that, "shubat*"*, is a very old tradition fermented camel milk form in Kazakhstan and "kheer*"* is very much famous among Rajasthan community.

Various naturally fermented camel milk products like Gariss, Chal, Shubat, Dhanaan, Airag, Butsalgaa, Arkhi, Tsagaa, Shmen and Yoghurt are available in different countries like Turkmenistan, Kazakhstan, Mongolia, India etc. (Solanki, *et al.*, 2018).

2.7.4 Camel milk cheese

According to Inayat*et al.*, (2003) Soft unripened cheese can be made from camel milk and the difficulty of making cheese from camel milk refers to technique witch will used. And so on, Cheese from camel milk cannot be produced by traditional way Konuspayeva *et al*., (2014) way. Based on that, Nada (2011) reported Salted cheese (1.0%) made from camel milk could be accepted by consumers in Sudan.

2.7.5 Camel milk powder and ice cream

Camel milk products, such as cream, milk powder and skim milk, were used to manufacture ice cream with a good flavor and texture. In addition, camels' milk powders were manufactured from fresh camel's milk (and various other products like fermented products, butter are also produced in other parts of world (Abu-Lehia *et al.*, 1989). Moreover, Camel milk products, such as cream, milk powder and skim milk, were used to manufacture ice cream and mixes made with 12 percent fat, 11 percent MSNF and 37 percent T.S. gave the highest scores for color, flavor and texture, as well as the overall acceptability.

According to Zayed, (2012), Camel's milk ice cream was found to contain only 2.5% fat, compared to that between 6 to 9 % for standard ice cream. In addition, it is safe for consumers with lactose intolerance and contained three times more vitamin C than cattle milk ice cream.

2.7.6 Cosmetics from camel milk:

Nowadays the knowledge of the cosmetic contents with camel milk uses the skin-friendly aspects for beauty treatments as well as Comparative Alternative Medicine (CAM) activities.

The activity of cosmeceuticals of camel milk is due to the specific milk components, whose efficacy is retained in skin preparations which have not been destroyed in their preparation (Yagil, 2017).

Camel milk not only has probiotic ingredients, but other important factors as well. The most pertinent properties of the camel milk (Yagil, 2013) which persist in the cosmeceuticals are fat, lactose, protein, vitamins c and electrolytes.

Camel milk shampoos quickly restore the health of the skin and hairs. The skin oils are cleansed by the camel milk and the antiviral and antifungal properties will prevent the activity of a yeast-like fungus (malassezia) or any negative immune response (Mayoclinic, 2013).

2.8 machine milking in Camels:

Camel farming is changing from traditional extensive to modern semi-intensive or even intensive system (Faye, 2013). Although modernization of camel's dairy industry is in progress, the use of milking machine is still in infant stages (Ziane *et al*., 2016).

Machine milking is widely spreading and practiced in she-camel many years ago and has become a regular procedure of highly dairy animals since it allows milking more animals per hour in better working conditions than manual milking. Furthermore, milking machine makes the possibility to collect a milk of better hygienic quality and good adapting for processing and marketing. The applying of milking machine technique in the less conventional dairy animals (sheep, goats, buffalo, camel, mare …) began to develop in recent years (Marnet, 2013).

Machine milking was applied with some breeders and in large scale farms around the world, in Russia (Baimukanov, 1974), United Emirate Arabic (Wernery, *et al*. 2006; Nagy 2013b), Tunisian (Ayadi *et al*., 2009; Atigui *et al*. 2014 a, b), Saudi Arabia (Aljumaah *et al.*, 2012; Ayadi *et al*., 2013).

The most commonly used milking machines for camels are slightly modified machines designed for milking of cows. Moreover, it was more efficient in collecting milk than hand milking, even if the dams were difficult to adapt to the machine-milking procedures (Hammadi *et al.,* 2010).

Interaction between animals and milking machine give us the mean to dapt machine milking to different case encountered during lactation (Marnet *et al.,* 2015).

Shehadeh and Abdelaziz., (2014) summarized the problems that faced the usage of machine milking in variations in the daily milk yield, lactation yield and length, the variations in morphological, anatomical and physiological aspects of camel udder and teats and the need of the presence of calves beside their mothers to stimulate milk ejection reflex.

Marnet *et al.*, (2016) described the different essential steps for camel milking machine development (knowledge of animal physiology, udder and teat shapes, teat functional characteristics, first functional data of milking including teat reaction, milk emission kinetic, efficiency of milk extraction, weaning procedure, milking procedure, milking behaviour of animals, adaptation of material and settings of the machine).

Hammadi *et al.*, (2010) reported that, daily milk yield was 38% higher in machine than hand milking system in camels. In addition, the lag time was half shorter in machine milking (36.0 ± 6.9 s) than in hand milking (58.0 ± 4.0 s). However, milking time was longer in machine than in hand milking and ranged from 4.2 to 4.8 min and 2.6 to 3.2 min, respectively. In addition to all practice, camels are sensitive, respond slowly and difficult to milking with machine. Consequently, camels must be accustomed to entering the milking parlour and being milked by the machine milking and the farmer must have basic knowledge of the behavior of camel and field experience in dealing with such animals.

The most important part of the milking machine is the liner, which is directly connected to the teat. Thus, the liner length must be adapted to the teat length. The use of short milking cups in camels (but suitable for cows) may be ineffective in the stimulation process. Nevertheless, the shape of the liner cup (conical or cylindrical), the diameter of the mouthpiece and softness of the lip, the quality of liner (natural, synthetic or silicon) are the main features of liner that must be taken into account to adapt to the teat (Marnet *et al.*, 2015).

Knowledge of morphology, anatomy and physiology of camel udder is necessary to develop an appropriate milking machines for camel (Caja *et al*., 2011).

2.9 Milk flow rate:

Udder milk flow presented useful and essential information on the course of milking including the milking efficiency and milk ejection (Bruckmaier and Blum, 1998). Udder milk flow parameters is also important for the genetic evaluation of the milkability (Duda, 1995). Furthermore, milk flow traits could be an important source of information related to the camel biology, milking machine performance and health problems (Tancin *et al*., 2003).

In Tunisia Atigui *et al.*, (2014b) reported an overall mean of 1·15 kg/min and 2·46 kg/min, respectively for average and peak milk flow rate for dromedary camels under an intensive farming system.

Compared to camel Strapak *et al.,* (2011) recorded an average milk flow rate of 2.52±0.75 kg /min and a maximum milk flow rate of 3.94±1.30 kg/min for Holstein dairy cows.

In buffaloes Boselli *et al.*, (2010) stated an average and peak milk flow of 0·86 and 1·36 kg/min, respectively.

Aydin et al. (2008), demonstrated an average milk flow rate, milking time and total milk yield per milking for Brown Swiss cow were 0.972 kg /min, 5.45 min and 11.35 kg respectively.

By small ruminants, Osuhor et al., (2003) reported an average of 3.6 g /s milk flow rate in for Sokoto dairy goats.

2.10 Milk flow curve parameters:

Milk flow curve described with the ascending phase, plateau phase and descending phase. On the other hand by the duration of total milking which consists of main milking phase duration (ascending, plateau and descending) , lag time and over -milking time (Atigui *et al.*, 2014b; Ayadi *et al.*, 2016; Strapak *et al.,* 2011; Tancin *et al.,* 2003; Antalik and Strapak 2011).

Three types of milk flow curves in Tunisian camels during milking identified by Atigui *et al*. (2014b): type 1; was portrayed by a higher peak flow levels followed by a declining phase without going through a plateau phase and have short milking durations which depend also mainly on the amount of milk stored in the udder. This type represents 40% of total curves and the milk yield per milking, average and peak milk flow were 4.24 kg, 1.49 and 3.54 kg/min, respectively among this type. Type 2; was characterize animals with relatively high milk production and lower milk flow rate, giving a larger plateau phase than type. This pattern ratio ranges about 38% and the milk yield per milking, average and peak milk flow were 3.30 kg, 1.12 and 2.12 kg/min, respectively. Type 3: show various patterns of milk flow, all characterized by low peak flow rate and a longer total milking duration. The proportion of this pattern is 22% and the milk yield per milking, average and peak milk flow were 2.34 kg, 0.65 and 1.23 kg/min, respectively.

2.11 Factors affecting milk flow curve:

The term milk flow curve refers to the graphical representation of the relationship between milk flow rate and length of time from the beginning of the milking to the end. The milk flow curve is composed of three segments or phases the first phase from initial milk flow rate up to the peak, the second phase is the persistency of the peak rate and the third phase is the decline from the peak to the end of milking.

The shape and the parameters of the milk flow curve depend on various factors, such as genetic traits, parity, bimodality and stage of lactation. However, there are some external factors affecting milk flow such as machine characteristics, milking routine and milking interval (Rasmussen *et al.,* 1993; Bruckmaier, 2001; Tancin *et al.,* 2006; Sandrucci *et al*,. 2007).

2.11.1 Stage of lactation:

In buffalo cow, Bava *et al.* (2007) recorded, Average and maximum milk flow rates were 0.92 ± 0.37 and 1.42 ± 0.60, respectively and milk flow rates decreased during lactation. On the contrary, lag time increased with increasing stage of lactation.

Strapak *et al.* (2011) studied the milk flow rate in Holstein dairy cows. He stated that, total milk yield, main phase and plateau phase of milk flow curve influenced by the lactation stage. Moreover, detected that, the highest total milk yield, average and maximum milk flow rates were in the group of cows at early stage of lactation, while the lowest values at late stage.

Tancin *et al.*, (2003) reported that, in dairy cow the milk yield and duration of milk flow decreased from 2 972 ± 226 g and 356 ± 23 s at early stage to 1 814 ± 210 g and 256 ± 21 s at late stage of lactation, respectively.

2.11.2 Parity:

There was great effect of parity on milk flow parameters in different lactating animals. The cows on their first lactation had lower production (2 188 ± 183 g) and the duration of milk flow (281 ± 18 s) than other cows (2 832 ± 90 g, 330 ± 11 s), respectively (Tancin *et al.*, 2003).

Strapak Peter et al, (2011) recorded highest total milk yield, average and maximum milk flow rates by dairy cows in the second lactation. While, the lowest values were measured in primiparous dairy cows.

Margetin *et al*., (2013) stated, there were no significant effect of parity on milk yield and milk flow traits in Slovak dairy ewes. In contrast, Walsh *et al.*, (2007) reported that, first-parity cows had the lowest average milk flow, peak milk flow and milking duration compared with all parities, whereas fifth-parity animals had greater peak milk flow and milking duration.

According to Di Palo et al, (2007) the Length of main milking phase was higher in pluriparous Mediterranean Italian Buffaloes *vs* primiparous group ($P<0.01$).

2.11.3 Bimodality:

According to Atigui *et al.*, (2014b) Bimodal curves occurrence in camels was 41·9% of total milk flow recorded curves. Moreover, machine milk yield was higher for bimodal curves compared with unimodal curves (4·09±1·01 kg vs. 2·97±1·03 kg. In addition she recorded bimodality curves of Seventy per cent in early lactation, against only 8·9% in late lactation.

Depending on the species, percentage of bimodal curves was lower for buffaloes (9%) in comparison with cows (Bava *et al*., 2007).

In terms of parity, Dodenhoff *et al*., (1999) stated that, the highest occurrence of bimodality was measured in second-lactation dairy cows.

Strapak Peter, *et al.* (2011) recorded a higher total milk yield (12.34 ± 3.42 kg) and average milk flow rate (2.56 ± 0.81 kg min^{-1}) in cows without bimodality curve. Moreover, he reported bimodality curves have twice longer incline phase of milking, which is leads to a decrease in the quantity of milk obtained during first minute of milking.

In other study to find out effect of bimodality on milking duration, Di Palo *et al*., (2007) concluded, the Length of main milking phase was higher in in bimodal milk flow curves *vs* the normal curves.

2.11.4 Milking interval:

Effect of milking interval on milk secretion rate in hand-milked camels was shown by AL Shaikh and Salah, (1994) in a study conducted in Arabian dromedaries for 4- to 16-h milking intervals in which the greatest milk secretion rate (585 g/h) was observed for the shortest milking interval and rates tended to decline with increasing milking intervals.

Ayadi *et al.*, (2009) reported that, milk secretion rate decreased according to increase in milking interval in lactating camels.

Caja *et al.*, (2011) reported that, milk accumulation in camels decreased markedly after 12 h milking interval, and no milking intervals longer than 16 h are recommended. No information is available on the effects of milking intervals on machine milking and milk flow rate in camels.

In dairy cows, Tancin *et al.*, (2006) stated that, all milk flow measures (plateau phase, average milk flow, beak milk flow and duration of total milk yield) were higher during morning milking except the duration of incline and decline phases.

According to Cho *et al.*, (2004) average milk flow rate and peak milk flow rate were highest with milking interval over than 13.5hrs in dairy cattle.

Regarding milking duration, Fahim *et al.*, (2017) reported that morning session was more time consuming (66.62±1.11 min) due to significantly higher yield in this session compared to afternoon and evening sessions in dairy cows.

Wagner *et al*., (2002) recorded a higher milking yield and longer total milking duration of morning milking compared with evening values in spite of no significant difference in milk flow between two sessions.

2.11.5 Milking machine characteristics:

Machine milkability is normally estimated by fractional milking (i.e. machine milking, machine stripping, and residual) or by analysis of milk flow curves obtained during machine milking (Caja *et al.*, 2000).

Marnet, (2013) demonstrated that, the main effects of pulsation rate are physiological by stimulating the neuroendocrine reflex of milk ejection and release of other galactopoietic hormones (prolactin, cortisol…).

According to Ayadi *et al.*, (2018) vacuum level of 45 kPa is sufficient to open the teat sphincter and drain cisternal milk. However, with high vacuum level, the peak flow rate (PFR) reached 2.31 ± 0.28 kg/min and the average flow rate (AFR) was 1.29 ± 0.19 kg/min. Daily milk yield and milk flow characteristics were positively correlated ($r=0.28$ to 0.53; $p<0.05$) during lactation.

Atigui *et al.*, (2014a) reported that, in Maghrebi camels the best combination of setting for camel's milking was high vacuum and low pulsation rate (48 kPa/60 cpm). Moreover, these setting resulted highest milk yield and average and peak milk flow rate, (3.05 ± 0.30 kg, 1.52 ± 0.21 kg/min, 2.52 ± 0.21 kg/min, and 3.32 ± 0.31 min, respectively), while milking time was the shortest.

Caria *et al*., (2012) stated that, the lower vacuum level resulted in a decrease in average and peak flow rate ($P<0.001$), and an increase in effective total milking time. Moreover, Vacuum levels of 37 and 40 kPa provided good milkability conditions, in which the plateau phase was longer than the decline phase in Italian buffalo's cow.

in camels, the use of milking machine with lower vacuum level (38 kPa) leads to extension of the milking time to the almost doubled and low efficiency in obtaining full milk from the udder. Higher pulsation rates did not stimulate the camels better during milking, and on the contrary, it induced more bimodality and lower milk flow rates (Atigui *et al*., 2015).

2.11.6 Milking routine:

Milk let- down is induced by allowing the camel calf to suck his mother for a while and then milking by hand or machine. Sometimes the she-camels refuses to be milked or to induce milk let- down if they are not familiar with the situation or the milker (Falah, 2004). Usually, camels are milked by hand in most countries of the world in traditional farming systems (Wernery, 2006; Nagy, 2013b), after the calf can suckle until the milk is let-down and then the camel can be milked (Bekele, 2010; Shehadeh and Abdelaziz, 2014).

In a large–scale system, the calves and dams are allowed together during machine milking (Juhasz and Nagy, 2008), being a factor necessary to induce the milk ejection reflex and milk let-down. But this process is not easily compatible with machine milking and need specific parlours designed to allow the mother-young interactions (Marnet *et al.*, 2015). Therefore, it is necessary to find an active process which stimulates the mammary gland before milking and induces the milk ejection without the presence of the calf during the milking process.

The increase of manual udder stimulation from 60 s to 120 s in camels tended to decrease the bimodal curves from 43.6% to 28.1%, respectively (Ayadi *et al.*, 2016).

Bruckmaier *et al*., (1996) reported, in cow stimulation of udder affected milk flow curve, whereas duration of milking machine was prolonged and peak milk flow rate was reduced during milking without stimulation. Moreover, time to reach milk flow plateau, time to reach peak flow rate was reduced.

Wagner *et al.,* (2002) recorded that, there were no significant differences in milk yield, milking unit attachment time, or milk flow for cows that were forestripped compared with dairy cows that were not forestripped.

Wernery *et al.*, (2004) reported that, machine stimulation caused udder oedema and mastitis. Wherefore, hand stimulation of two to three minutes was well accepted and duration of milking was decreased after the first three months of milking. In the relation to the udder measurements, Mello *et al.* (1998) reported that, the udder circumference had a significant effect ($P<0.01$) on milking time and milking rate.

2.12 Udder and teat morphology:

2.12.1 External measurements:

Assessments of the udder and teats measurements are necessary aspects for improving milk yield and machine milking ability of dromedary camels.

For external udder measurements in intensive system, Ayadi *et al.* (2013) recorded 44.50 ± 0.64 cm, 49.68± 0.90 cm, 107.48 ± 1.44 cm, 9.69 ± 0.64 cm, 2.31 ± 0.09 cm for udder depth, udder length, udder height, distance between teat and milk vein diameter respectively.

Eisa *et al.* (2010) recorded that, Udder depth, circumference, vertical semi circumference and size scored 16.9 ± 2.5 cm; 91.4 ± 10.0 cm; 52.0 ± 5.6 cm. and 1559.5 ± 388 cm3. , respectively. While udder height at fore and rear quarters were 111 ± 7.1 cm; and 110 ± 7.6 cm respectively. Length of fore and rear teats and distance between right teats and that between left teats were 4.3 ± 1.4 cm; 4.4 ± 1.5 cm; 3.1 ± 1.8 cm and 3.0 ± 1.5 cm, respectively. However, the average length of the teat was 3.2 cm, whereas the average diameter of the teat was 1.4 cm at the base and 0.8 cm at the apex and the distance between the front teats was greater than that in the hind teats.

Abdallah and Faye (2012) estimated some udder measurements of the Dromedaries camel in Saudi Arabia and showed some individual udder and teat length changes among types such that values ranged between 6-50 cm and 1-26 cm, respectively.

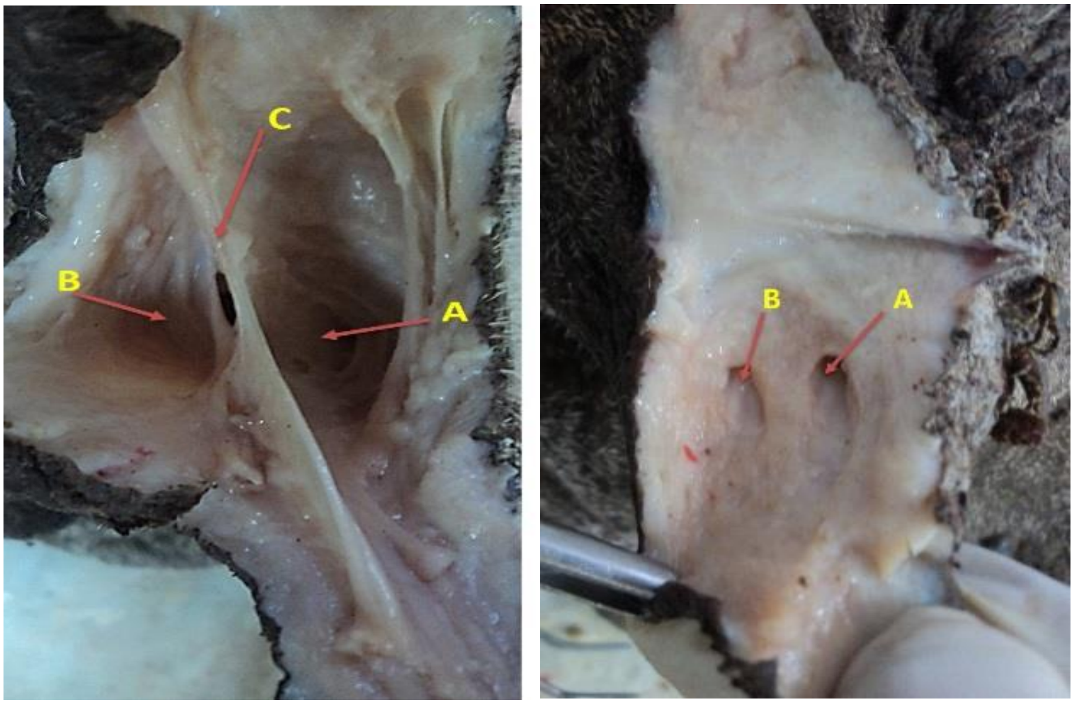
Zayeed *et al.* (1991) studied the udder measurement in Libyan dairy camel and they reported that, udder length 24 cm, width in the fore teat 36 cm, depth in the fore quarters 17 cm, depth in the rear quarters 13cm. The distance between the fore teats 22 cm, and between the rear teats 12 cm, they also reported that the fore teats is less in size than the rear teats, and their length are between 3.2-1.3 and 5-1.8 cm., respectively. The diameter of the fore and rear teats (in the base of the teats) were 4.5-1.8 and 4.9-2.1 cm, respectively.

2.12.2 Internal measurement:

According to Rizk *et al.,* (2017) the udder of the she camel consists of four quarters; each has two separate milk systems without external demarcation between them (Figure 2.3). Moreover, the udder of she-camel is divided into four quarters, two rear quarters and two fore quarters. Every quarter consists of two or three separate units each leading to a separate streak canal within the respective teat. This means that the camel's mammary gland possesses at least 8 (4 x 2) independent milk units (Wernery, 2006).

Abshenas *et al.,* (2007) recorded that, the teat canal length, teat end width, teat wall thickness, teat cistern width, and mid cisternal wall thickness, were measured in ultrasonography scans in camels averaged (9.33± 0.35, 14.58 ± 0.33, 7.91± 0.49, 4.66± 0.18, 2.75± 0.13), (9± 0.38, 14.91±0.28, 7.75 ± 0.32, 4.62± 0.18, 2.58± 0.14) in anterior and posterior teats respectively.

Atigui *et al.,* (2016) stated that, teat length estimated by ultrasonography was significantly higher than external measurements taken by Vernier caliper. However, no difference was noted between internal and external teat diameter. Szencziova Iveta *et al*., (2013) in dairy cows determined internal differences in teats before and immediately after milking via ultrasound, the average length of teat canal, teat diameter and Teat wall thickness measured were (10.73 mm ,13.13 mm), (0.66 mm, 0.78 mm), (6.09 mm, 8.51 mm), before and after milking respectively.



Gland cisterns of one quarter of the lactating camel A. cranial gland cistern lumen, B. caudal gland cistern lumen, C. inter cistern wall

Teat cistern (opened) of the udder lactating camel A. cranial teat cistern, B. caudal teat.

Figure 2.3 internal anatomy of udder and teats in lactating camel (Rizk *et al.,* 2017)

2.12.3 Change of the udder and teats measurements:

There are a number of factors in milking that influence the condition of the teats such as vacuum level, pulsation rate, and the teat cups. The use of the high working vacuum level can cause irritation in mammary tissues, congestion and oedema of the teat tissue, especially at the teat end, and influence teat diameter (Hamann, 1990; Rasmussen and Madsen, 2000).

Teats are frequently enlarged and deformed and there is significant size and volume change during lactation (Juhasz and Nagy 2008). Kusar *et al.,* (2001) stated that the teat length increased ($P<0.05$) in lactating compared to non-lactating she camel. While the circumference at apex and mid points of teat decreased significantly ($P<0.05$) in non-lactating compared to lactating camels.

Zayeed *et al.*, (1991) studied the udder measurements before milking and during milk stimulation and reported that, the length of fore right, fore left, rear right and rear left teats were 12, 12, 13 and 13 cm, respectively. The diameters of the teat in the upper were 8, 7, 11 and 11 cm, respectively and in the lower 10, 9, 13 and 12 cm, respectively. Udder depth with teat were 36, 36, 39 and 40 cm, respectively, and without teat 25, 25, 26 and 28 cm, respectively. The distance between fore right and left teat 18 cm, and rear right and left teat 12 cm. The width of the udder between the fore, rear, right and left teat were 22, 24, 16 and 14 cm, respectively, (from the middle of the teats). The width of the udder in the upper and lower were 27 and 25 cm, respectively.

Zayeed *et al.* (1991) demonstrated that, there is great variation in teat size and length in camels, and this is due to some reasons such as camel type, lactation stage, parity number, the ability of the she-camel to milking procedure and udder and teat disease. The author's furtherly revealed that, the same reasons have an effect in the udder size and milk production.

In Brown Swiss cows, Tilki *et al.*, (2005b) mentioned distances between front teats and between rear teats tended to be increased before and after milking with advancing lactation number. While, the distances were wider before milking than after milking. Furthermore, Front and rear udder heights tend to be decreased with advancing lactation number and front and rear udder height before milking was lower than that after milking.

Increase of teats diameters immediately after milking (indicator of congestion of teats) was observed in dairy cows milked by 50 kPa (Hamann *et al.*, 1993). Little is known about the effect of vacuum levels on teat changes and udder health of dairy camels (Ayadi *et al.*, 2015).

In Cameroon, Mingoas *et al.*, (2017) showed that, the udder depth significantly increased ($p<0.05$) at the 3rd parity and decreased at the 3rd stage of lactation. While, the udder height increased ($p<0.05$) at the 2nd parity and decreased at the 3rd stage of lactation in zebu cows.

Zwertvaegher *et al.*, (2012) reported that, in Holstein cows, udder depth and height significantly decreased at third lactation stage, while there were no significant variations of teats morphology with respect to lactation stage.

In dairy cows Tina *et al.*, (2014) reported that, teat size was not correlated to milk production. However, a study on Tinerfen breed goats in Spain Capote *et al.* (2006) stated that udder characteristics related to its globulousness such as volume, perimeter of insertion, and distance between teats are more reliable for milk yield evaluation. The teats are the most stressed part of the udder, because milking changes their condition (Hillerton *et al.*, 2002).

2.12.4. Cisternal and alveolar udder compartments:

Camel as in other dairy animals, milk accumulates in the udder and is stored within two compartments: the cistern (including teat and, gland cisterns and in large and medium milk ducts) and the alveoli (alveoli and small milk ducts) (Figure 2.4). However, the udder cistern of camel is absent or has very small volume and therefore, only a small cisternal fraction of milk (4-10%) is available (Juhasz & Nagy, 2008; Caja et al, 2011; Atigui *et al*., 2014a; Ayadi *et al*. 2016) and the alveolar fraction of milk is large (90-95%) (Caja *et al*., 2011).

According to (Bruckmaier and Blum, 1998) milk within the udder can be divided into two fractions: cisternal milk which is immediately extracted by the machine without oxytocin release; and alveolar milk which can only be removed by the active involvement of the animal, when oxytocin release and milk ejection occurs.

The amount of cisternal milk decreases in late stage of lactation compared with early and middle stage of lactation (Atigui *et al,* 2014a).

Yagil *et al*. (1999) assumed that, camels do not have noticeable mammary cisterns. Otherwise, Baimukanov (1974) suggested that camel cisternal milk represents only 10% of the total machine milked milk.

According to Ayadi *et al*. (2009) Tunisian Maghrebi camel udder showed small cisterns (19.3% of total milk the udder at 24 h) when compared with other dairy animals.

Caja *et al.* (2011) in camels found that, a mean cisternal milk ratio at 4, 8, 12, 16, 20, and 24 h milking interval and at mid lactation, equal to 7.4 % of total milk stored in the udder. Moreover they reported that, the cisternal milk can immediately be removed by suckling, hand and machine milking, whereas the alveolar milk is not available before it is actively shifted into the cistern by a positive pressure on the alveoli in response to the hormone Oxytocin after inducing the milk ejection reflex.

Atigui *et al*. (2015) stated that, cisternal milk yield in camels was significantly higher at early and middle lactation (269.1 ± 30.7 and 293.0 ± 71.2 ml) respectively compared to late lactation (70.80 ± 15.7 ml).

Costa *et al.* (2004) supposed Buffalo cows have similar udder cistern of camel and almost 95% of the milk is stored in the alveolar compartment.

In dairy cows Caja *et al.* (2004) reported that, Cisternal milk and cisternal area were correlated (r = 0.74 to 0.82) for all stages of lactation. Furthermore, as lactation advanced, volumes of alveolar and cisternal milk and cisternal area decreased. Proportion of cisternal milk varied between stages of lactation (early, 33.2%; mid, 23.1%; and late, 42.6%).

In Najdi sheep Ayadi *et al.* (2014) mentioned that, cisternal milk accounted for 55% and 67% of the total udder milk during suckling and milking periods, respectively and cisternal milk was positively correlated ($r=0.93$, $p<0.05$) with total milk yield.

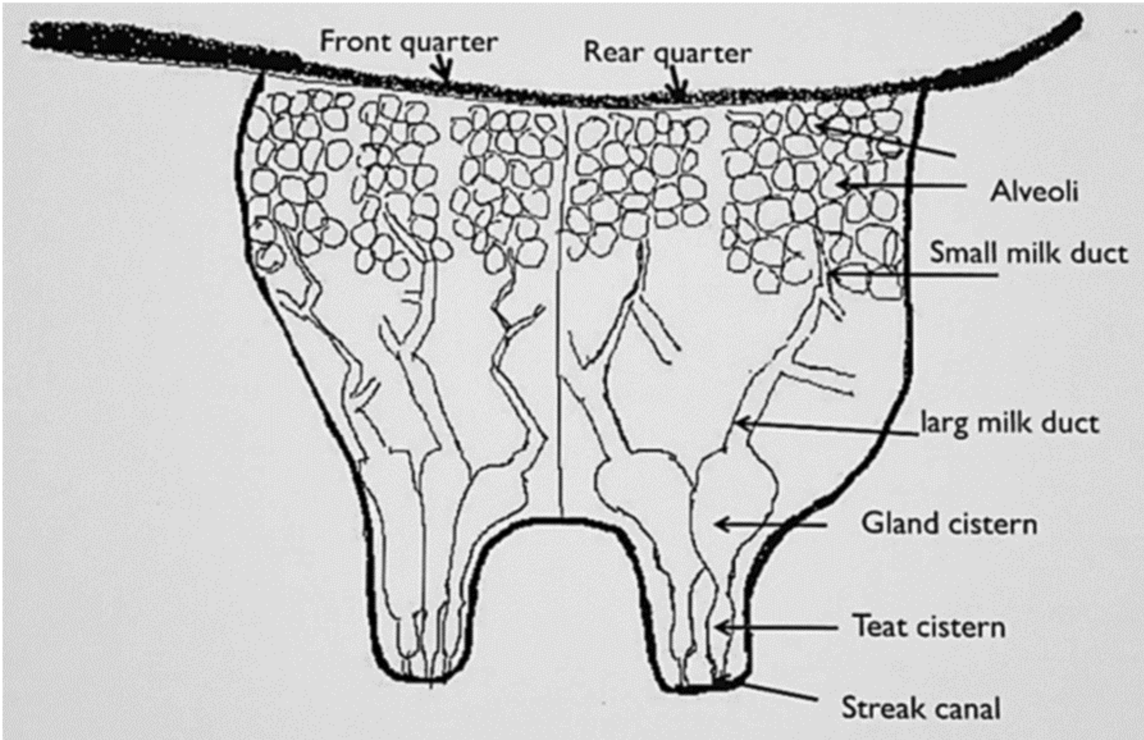


Fig 2.4: Schematic representation alveolar and cistern compartment in camels (Shehadeh. 2018).

2.13 The correlation between udder measurements and milk yield:

The relationships between udder characteristics and milk yield can be useful tools in selecting animals in dairy production systems.

Eisa *et al*. (2010) showed that the udder depth, udder circumference, udder size and length of fore and rear teats were positively and significantly correlated with milk yield in dromedary camels, whereas the height of the udder measured for both fore and rear quarter was negatively but insignificant correlated with daily milk yield in camels. While, diameter of fore and rear teats were positively but insignificant correlated with daily milk yield.

In Saudi camels, Ayadi *et al.*, (2013) recorded positive correlations between udder height as well between teat length and diameter, while negative correlation was obtained between teat diameter and distance between teats. Furthermore, milk yield was correlated positively with udder depth, distance between teats, and milk vein diameter, while a negative correlation was found with udder height.

Patel *et al.*, (2016) reported that the correlations between milk yield and various udder measurements viz., udder length (0.499), udder width (0.413) and udder depth (0.178) were found positive and significant. ($P<0.05$) to highly significant ($P<0.01$) in crossbred cows.

In Sudan, significant ($P<0.05$) correlation of udder length (0.64) with milk yield in Kenana × Friesian crossbred cows was reported by Deng *et al.*, (2012).

In Turkey various udder characteristic and their relationship with milk yield in Simmental cattle from Kazova farm, were determined by Sekerden *et al.* (1997) they reported that, statistically significant partial correlation coefficients, ($P<0.01$) and ($P<0.05$), were found between 305 days milk yield and various udder and teats characteristics, particularly for udder length and width of front udder.

Ayadi *et al*., (2014) reported that daily milk production is positively correlated to distance between teats ($r=0.61$, $p<0.05$) and udder depth ($r=0.29$, $p<0.05$) in Najdi sheep.

In Chile, Angeles (2014) recorded positive correlations of 0.77 ($p<0.0001$) between udder depth and milk production and 0.60 ($p<0.0001$) between udder height and milk production in local cows.

Khan and Khan, (2016) found genetic and phenotypic correlations between udder biometrics and milk yield in Pakistan Sahiwal cows.

In Brazil, Mello *et al.* (1998) investigated udder morphometry in goats, they reported that, the udder circumference had significant effect ($P<0.01$) on daily milk yield and the correlation of udder circumference with daily milk yield was (0.78).

In Spain dairy sheep Rovai *et al*. (1999) stated that, at all stages of lactation, positive correlations were observed between udder size measurements (depth, length and distance between teats) and milk production ($r = 0.72$).

2.14 Udder and teat shape in relation with milk productivity:

Shehadeh and Abdelaziz, (2014) showed that, one of the constraints facing machine milking in camels is the variations in morphological, anatomical and physiological aspects of camel udder and teats.

Ayadi *et al*., (2016) stated that, in camel globular udder shape (47.3 %) was the most common, followed by pear (34.3 %) and pendulous (18.4 %) shapes. Moreover, conical or funnel teats was the most frequent shape (63.2 and 58.7

% for fore and rear teats, respectively) followed by cylindrical (26.4 and 32.5 %, respectively) and blew-up shaped teats (8.7 and 10.4 %, respectively).

Marnet *et al*. (2015) mentioned that, the best udder and teat shape is the important point before adoption to machine milking. A large udder with high attachment that avoids contact between cluster and ground, equilibrated quarters in volume and milk flow for a simultaneous emptying, vertical teats to avoid folding of teats and homogeneous shape (cylindric or conical) and dimensions between teats are the main characters to select. In addition they mentioned that, Commercial flocks in Tunisia showed 3 main teat shapes. The best one is cylindrical teats (39%) followed by conical/funnel teats (41%) and irregular shaped teats (20%) that need to be eliminated by selection.

Shehadeh., (2018) summarized a good camel udder for machine milking by, the following properties: a large amount of glandular tissue, uniformly shaped and it has a vats or bowl shape, the teats are well established, medium long teats (5-7 cm) and the teat diameter is 2.5 cm and they have a correct position. Furthermore, he mentioned, this udder is good for machine milking and the cups are well attachable, all quarters are emptied rapidly at the same time.

In Murrah buffaloes, Prasad *et al.*, (2010) recorded that the average teat lengths in different udder shapes were 7.33 ± 0.16, 7.80 ± 0.38, 8.98 ± 0.48 and 9.28 ± 0.61 in bowl, globular, goaty and pendulous udders respectively. Similarly the average teat diameter in buffaloes with various udder shapes were 2.76 ±0.03, 2.75 ± 0.06, 2.60 ± 0.01 and 2.93 ± 0.09 in bowl, globular, goaty and pendulous udders respectively. Moreover, summarized the average daily milk yield with various udder shapes as 6.41 ± 0.33, 5.91 ± 0.26, 5.61 ±

0.32 and 6.31 ± 0.16 kg in bowl, globular, goaty and pendulous type of udders, respectively.

In dairy cows, funnel-shape teats produced more milk than cows with cylindrical-shape teats, at a similar lactation stage and age (Prajapati *et al*. 1995).

Tilki *et al.*, (2005a) in Brown Swiss cows recorded a means of 305-day milk yield for cylindrical, funnel and bottle teat shape groups were 3156, 3169 and 2377 kg, respectively.

Kausar *et al.* (2001) have reported that, the udder- and teats form changed markedly in dromedary camels in Pakistan with the change in the physiological status. They reported, the conformation of teats turned noticeably round at the tip, the morphometrically data revealed that teat length at maturity increased twice the size of immature heifer (7.95 ± 0.01 vs. 3.23 ± 0.26 cm).

Saleh *et al.* (1971) found in the dromedary camels in Egypt that the fore-teats are placed further apart from each other than the rear ones and the teat in general is short and cone-shaped and somewhat flattened from side to side. Furthermore, they showed that both fore and rear teats are almost equal in length

Chapter Three
Materials & Methods

CHAPTER THREE

Materials and methods

This study is composed of two parts. The first part of the study discussed the methods used in the study of milk flow traits during lactation. While, the second part was aimed to investigate change in udder and teats measurements before and after milking during lactation and assessed the udder and teat shape in relation with camel milk yield.

3.1 Experiment 1: milk flow traits during lactation:

3.1.1 Study area: -

The first experiment of the study was conducted at the Conservation and Genetic Improvement center (Al-Kharj district, Riyadh, Kingdom of Saudi Arabia).

3.1.2 Animals and their management: -

A total of 22 multiparous dromedary camels (8-12 years old) were kept indoors throughout the year and housed in pens. All camels had free access to water. The herd was composed of four Ecotypes camels (Malhah, Wadhah, Hamrah and Safrah) but belonging to very close genotype (Almathen *et al.*, 2012). The original herd of females was transferred from Al Jouf "Camel and Range Research Center, "Saudi Arabia. Al Jouf center is located in the north-west of Saudi Arabia during mid-2013s and increased in numbers by purchasing from breeders. Most of the sires used for natural mating were born in the center. Selection was based on their own conformation and weight and on milk yield of their dams. Natural mating was practiced. Usually, females that were in oestrus were presented to males during the year following calving.

As the calving season occurred between December and February, all the camels were approximately at the same stage of reproductive cycle. After birth, she-camels and their newborn calves were kept together for about 2-4 weeks. All camels were drenched against internal parasites every 6 months and sprayed against external parasites every month, and any camel found sick was treated.

Camels were selected to have close teat shape and dimension. The daily feeding routine for lactating camels was *ad libitum* alfalfa hay and 3 kg/head of commercial pellets (Wafi®, ARASCO. Riyadh, Saudi Arabia). Camels had free access to fresh water. Lactating dromedary camels suckled their calves freely during the 1st month of lactation. Thereafter, the dams were introduced to machine milking. Calves weaned definitively at 6 months of age, leaving the dams to continue their lactation for another 6 months.

3.1.2.1 Camel identification: -

All camels were identified by electronic ceramic boluses (Rumitag, Esplugues de Llobregat, Barcelona, Spain) according to Salama *et al.*, (2012). The boluses contained a 32 × 3.8 mm radiofrequency transponder (Ri-Trp-RR2B-06, Tiris, Almelo, the Netherlands) working at a low frequency (134.2 kHz). An electronic identification was implemented using the system Datamars ® (Switzerland) based on the introduction of bolus in the stomach and reading with electronic reader stick placed under rumen.

3.1.3 Parlor and Milking machine parameters: -

Camels were machine milked twice a day (6:00 and 16: 00) in single – tunnel milking parlor equipped with medium- pipeline (1.8 m) milking stalls and electronic pulsator (BouMatic, Itak Company, Riyadh, Saudi Arabia). The weight of milking cluster and diameter of mouthpiece liners were 1.9 kg and

25 mm, respectively. The milking machine was set at 45 kPa, 60 pulsations/min, and 60:40 pulsation ratio. The milking routine included: milk let-down by calves (without suckling); udder preparation (teat and udder washing and drying), machine milking and final stripping, by the calf.

3.1.4 Milk flow traits: -

The 22 dromedary camels were used in the study. Camels were machine milked twice a day. A total of 921 milk flow curves were registered during lactation. The milk production and milk flow parameters were weekly recorded two times a day in the morning 6:00 and evening milking 16:00 by using two electronic mobile milk flow meters - (Lacto order©, WMB, Balgach, Switzerland), specially calibrated to low milk flow rate (< 0.05 kg /min). The Lactocorder was connected between milking equipment's and the clusters before each milking (photo 3.1). Thirty parameters were recorded including total milk yield, machine milk, machine striping milk, average milk flow rate, peak milk flow, duration of ascending phase, duration of main phase of lactating, duration of descending phase, duration of stripping phase, percentage of bimodality.

Photo 3.1 Recording of milk flow parameters' by the lactocorder.

3.1.4.1 Assessment of milk flow curve phases:

The milk flow curve was describe by seven parameters (figure 3.1):

1. Ascending phase: from milk flow rate 0.250 kg/min until the start of plateau phase.
2. Plateau phase: phase of steady flow until the slope of milking flow.
3. Descending phase: from end of plateau until milk flow dropped below 0.2 kg /min
4. Stripping phase: period at the end of milking, with milk flow rate > 0.02 kg /min for at least 4.2s.
5. Peak milk flow rate (PFR): the maximum milk flow during 22 s.
6. Average milk flow rate (AFR): calculated from duration of main milking (sum of ascending, plateau, descending phase).
7. Total milking time (machine – on time): sum of all the phases (ascending, plateau, and descending, dry phase and stripping phase) from attachment until clusters removal, (fig 3.1).

Data were divided according to stage of lactation (first, mid and late), milking time (morning and evening) and milk emission kinetic patterns (mono-modality and bimodality).

3.1.4.2 Milk flow traits according to stage of lactation:

The 43 weeks of lactation was divided in 3 periods:

1. Early stage of lactation: 6 to 16 weeks (n=282)
2. Mid stage of lactation: 16 to 32 weeks (n=363)
3. Late stage of lactation: 32 to 43 weeks (n=277)

3.1.4.3 Milk flow traits according to milking intervals: -

The intervals of milking depend on milking time, the data divided to:

- Morning milking with interval of 14 hours (n=476)
- Evening milking with interval of 10 hours (n=445).

3.1.4.4 Milk flow curve pattern:

Milk flow curves divided into two types:

- Bimodality: presence in milk flow curve of 2 increments separated by a drop-in milk flow (Figures 3.2, a).
- Normal modality: regular milk flow curved from the beginning to end of milking (Figures 3.2, b). Milk emission kinetic patterns represented milk flow curve with bimodality (n= 270) and normal milk flow curve (n=651).

3.1.5 Calculation of persistency:

Persistency was calculated as the percentage of daily milk yield from the peak to the end of lactation: $P = [1- ((ym – y360)*(30d/dbt)) / ym] *100$ Where P is percentage persistency, ym is daily milk yield at peak lactation, y360 is milk yield at the end of lactation, 30d is one month and dbt is the number of days between tests.

3.1.6 Statistical analysis: -

The measurement results had been subjected to statistical analysis using the SAS program (SAS 2012). Means procedures were used for general description. General Linear Model (GLM), Least Squares Means (LSMEANS) procedures were used to investigate the effect of stage of lactation, milking session and bimodality. Pearson correlation coefficient between all traits was performed by using CORR procedure.

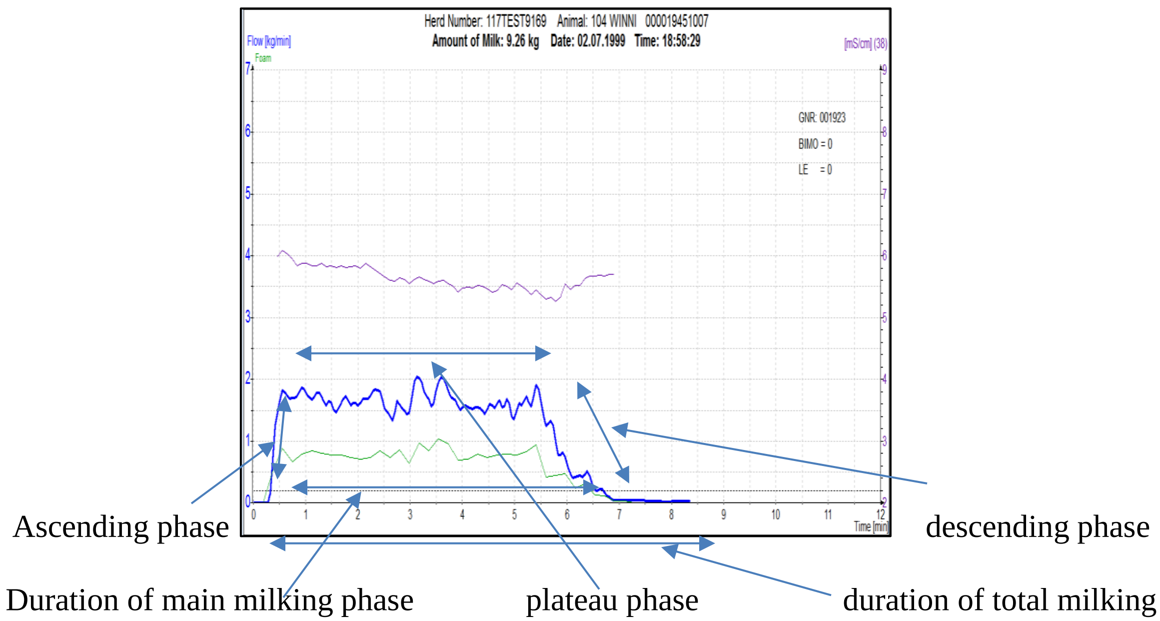
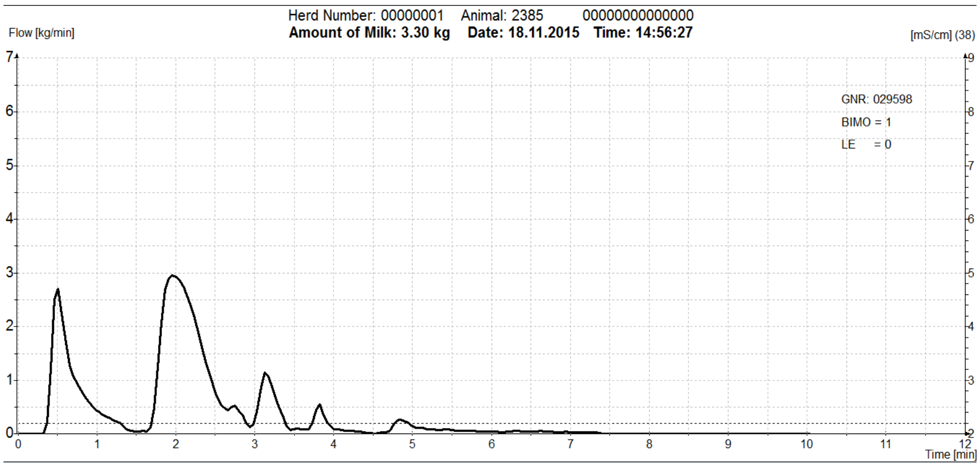
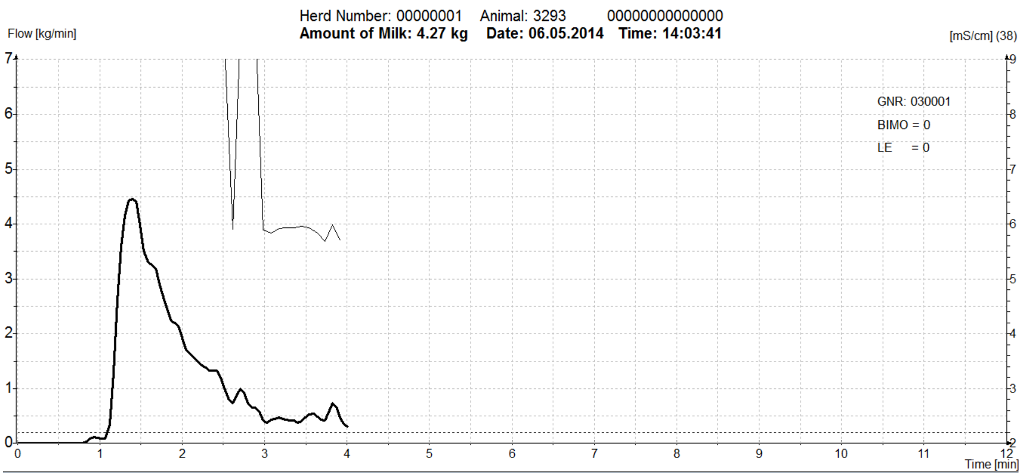


Fig 3.1 Milk flow phases and the duration of milking in dromedary camel.



(a)



(b)

Fig 3.2. Examples of bimodal (a) and mono-modal (b) milk flow curves for dromedary camel

3.2 Experiment 2: Udder and teats measurements and shape: -

3.2.1 Study area:

The second experiment of the study was conducted at Al-Turath Al-Saudi Company, large – scale camel dairy farm (180 km northeast of Jeddah, from KSA) situated at 22˚.97 ″N and 39˚.91″ E latitude.

3.2.2 Animals and their management: -

A total of 77 multiparous dromedary camels (7-10 years old) were used to study the evaluation of udder morphology traits throughout lactation. Each of the selected lactating camels was identified by plastic ear tag with numerical No. All calves suckled their dams freely until 40 days of age. Subsequently, they were on partial suckling regime all the night for 20days when their dam was machine milked once daily. Therefore, all calves allowed suckling, leave one hour after machine milking until they were completely weaned at five months of age.

The she camels were machine milked twice a day (06:00and 16:00h) in a double-tunnel milking parlour which consists of two rows with 10 camels on each side and equipped with low-pipeline milking stalls (Agripadana Podova, Italy Company, Riyadh, Saudi Arabia), electronic pulsators and listed measurable milk recording system allowing reliable and continued collection of milk yield data of individual camels. The weight of the milking cluster and the diameter of the mouthpiece liners were 1.6kg and 25mm, respectively. The milking machine was set at 45 kPa, 60 pulsations/min, and 60:40 pulsation ratio. All camels had clinically healthy udders. Determination of udder health was performed at the day before a control day at different stage of lactation by CMT. The milking routine included: milk let-down (without calves suckling); udder preparation (teat and udder washing and drying), machine milking and machine striping milk.

3.2.3 Experimental animals feeding:

In the intensive system of Al-Turath Al-Saudi Company, large – scale camel dairy farm, all camels under intensive feeding management and were housed in open air shade pens. A feeding plan based on restricted feeding system (versus ad libitum feeding system) was used to meet the requirement of camels according to their production stage to avoid any excess fat deposition in the hump. An alfalfa and straw based diet was supplemented with concentrate. The lactating camels were supplemented with 5 kg of commercial concentrate pellets (WAFI®, ARASCO) besides 3 kg of alfalfa per head. Daily diet of camel calves consisted of 1 kg concentrate and 1.5 kg of alfalfa was supplemented. Fresh water was provided *ad libitum*. Salt and standard minerals were mixed with the feed concentrate.

3.2.4: Change in udder and teats measurements during lactation:-

Two hundred and eight multiparous lactating dromedary camels of the Al-Awarik breed (Faye et al., 2011) at early (wk=10; n = 77), mid (wk=24; n = 67) and late lactation (wk=40; n = 64) were included in the data set, with similar parities and ages randomly selected from the herd. Camels were kept in barns all the time in intensive farming system. Each of the experimental selected females was identified by plastic ear tag with numerical No. A record for each she-camel such as, calving date and daily milk yield was compiled. Udder and teat morphology traits for all camels were measured before and after morning milking at first, mid and late lactation. All camels had clinically healthy udders. At the start of the experiment all camels were diagnosed free of mastitis by California mastitis test (CMT).

3.2.4.1 Determination of udder morphology: -

Measurements of udder and teat morphology were taken in milking parlour two times directly before routine pre–milking treatment and directly after removal of milking cluster. The following measurements were done according to Ayadi et al. (2013), (Figure 3.3).

3.2.4.2 Daily milk yield:-

Individual milk yields from morning and evening milking were measured using cylinders recorders attached with the milking machine for each cluster. The milk production not including part drunken by camel calves was recorded every day (photo 3.2).

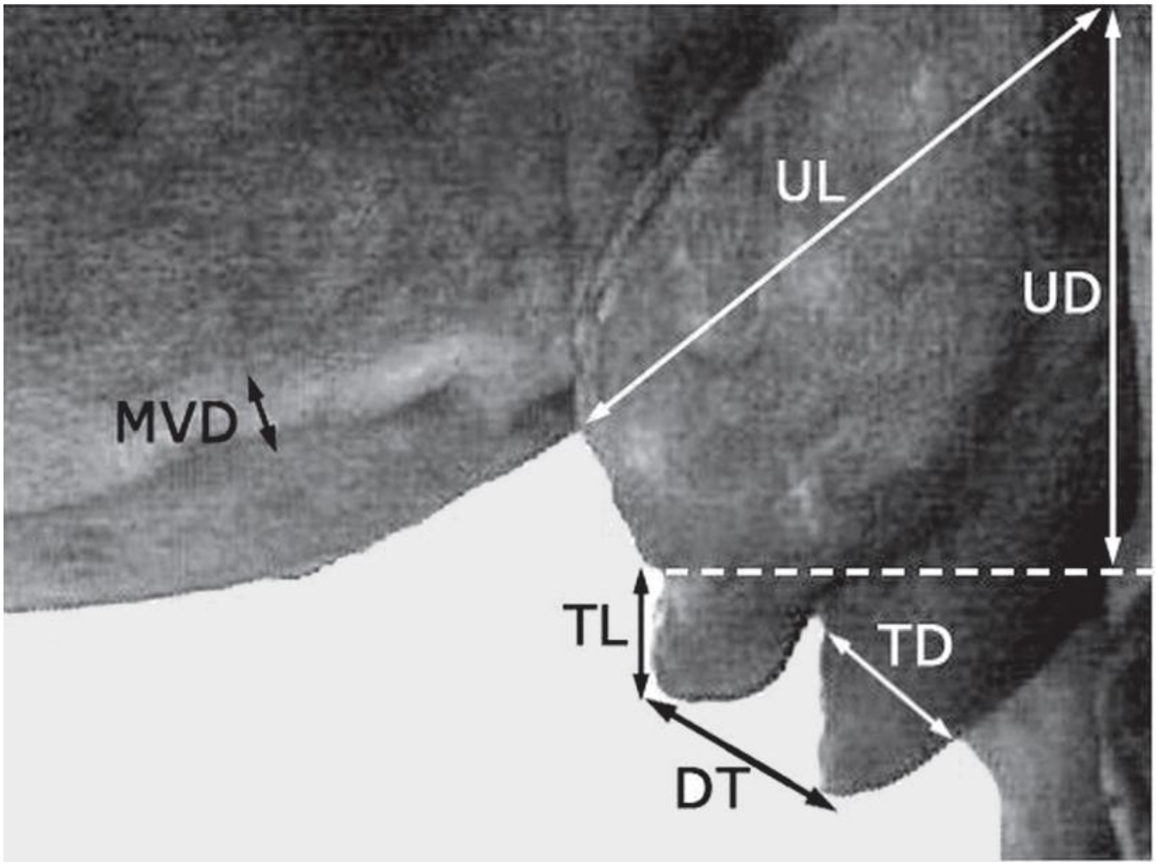


Figure 3.3: Measurements of udders and teats morphology in dairy dromedary camels. UD: udder depth. UL: udder length. TL: teat length. TD: teat diameter. DT: distance between teats. According to Ayadi et al (2013)

3.2.4.3 Statistical analysis: -

Udder measurements and milk yield changes (mean and SD) were reported at early, mid and late lactation stage. Pearson correlations between different udder and teat parameters were calculated. The effect of udder and teat morphology traits and milk yield were examined by ANOVA procedure. The types of udder based on their multiple measurements, were determined by using Hierarchical Classification Analysis (HCA) on Ward distance applied on a matrix including 208 camels' measures during three lactation stages and 7 columns (teat and udder measurements). Relationships between type of udder and milk yield was determined by ANOVA. Data from the present study were analysed by using XLSTAT software (2012, 02 version Addinsoft©).

Photo 3.2 cylinders milk yield recorders attached with the milking machine for each cluster. Al-Turath Company – Jeddah. (Musaad M. A 2015).

3.2.5 Determination of udder and teats shape and the relationship with milk yield:

3.2.5.1 Udder morphology and typology:

Multiparous dromedary camels were used to study the evaluation of udder morphology traits and typology throughout early (n=72) and late (n=60) stage lactation. All the camels had clinically healthy udders. Udder and teat morphology traits for all camels were measured before morning milking. Measurement of udder and teat morphology was taken in milking parlor two times directly before routine pre-milking treatment. To evaluate the udder and teats shape duplicated images were taken from left side of each camel with the same distance and angle from the udder. by digital camera (Sony DSCW530, 14.1MP, compact digital camera), clear images of udders and teats stored directly in a computer to assess the udder and teats shape as a completion of the data with the udders and teats measurements and milk production for each lactating camel involved in the study. Thus, the shape of the udder was classified as pear shaped; Globular shaped and pendulous shaped, while the teat was classified as funnel shape; cylindrical shape and bottle shape (fig 3.4).

3.2.6 Statistical analysis

Udder measurement and milk yield changes (mean and SD) were studies at early, mid and late stage of lactation. The correlation between different udder and teat parameters were calculated using person correlation. The effect of udder and teat morphology traits and milk yield were examined by ANOVA procedure. The obtained data were analyzed using the statistical analysis System (SAS Inst., Inc., Cary NC, USA. 2010).

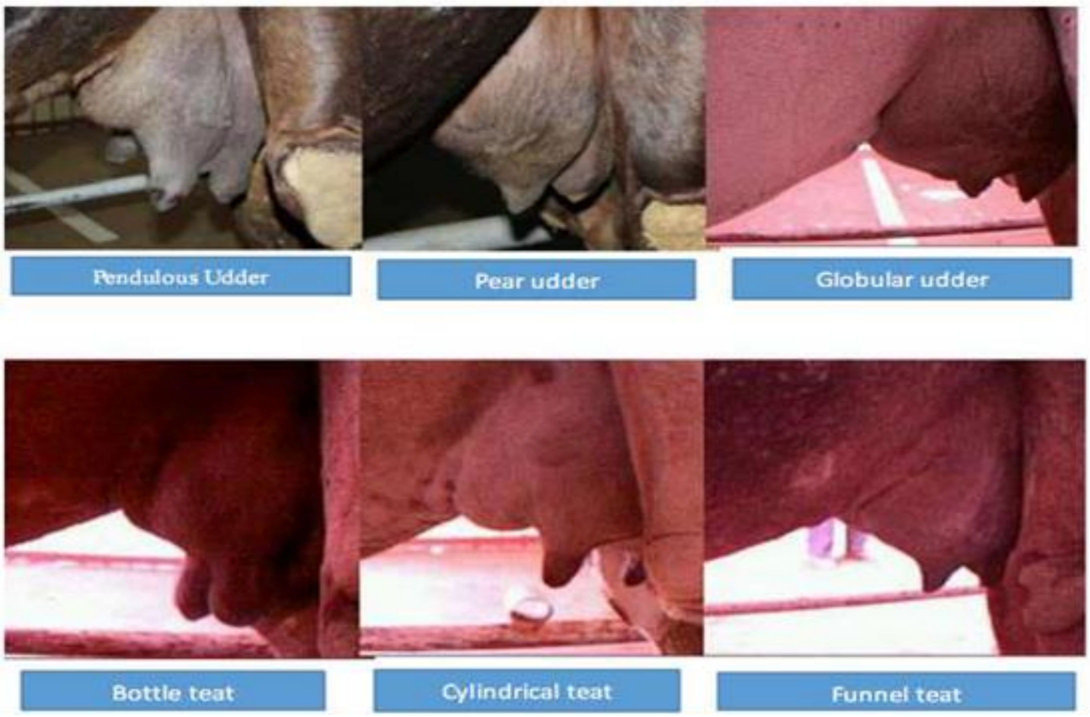


Figure 3.4: Udder and teat shape of dairy dromedary camels.

Chapter Four
Results

CHAPTER FOUR
Results

4.1 Experiment 1:-

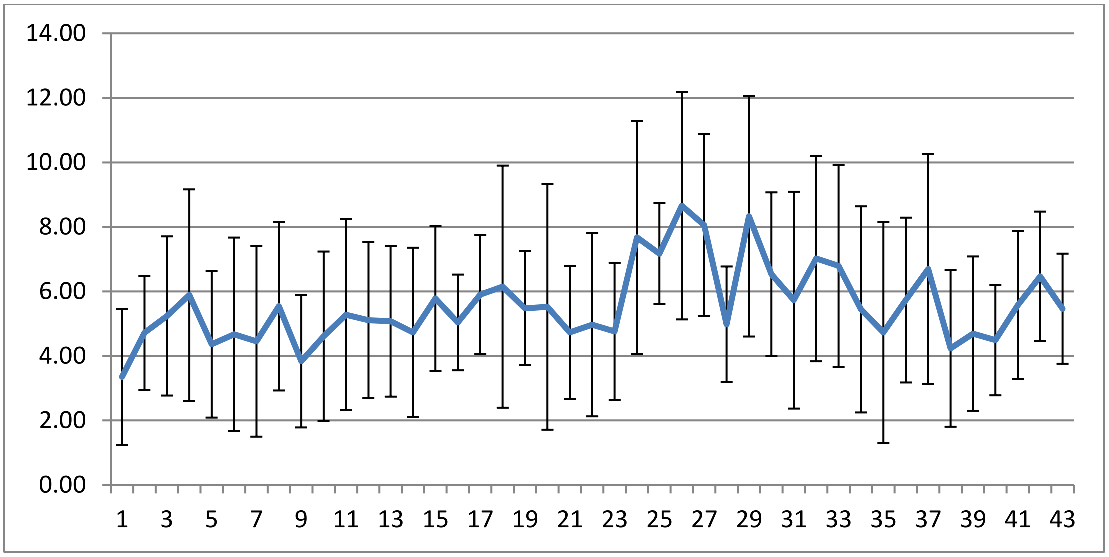
4.1.1 Lactation curve: -

According to lactation curve based on weekly total milk yield (43 weeks of lactation), Milk yield varied between 3.35±2.1 l and 5.46±1.71 l at the sixth week and the end of lactation (43^{th} week) respectively, with a mean value of 5.57 ±2.6 l. Peak lactation started from the 24^{th} week with the value of 7.67±3.60 l up to the 26^{th} week with 8.66±3.53 l. Peak yield decreased slightly to reach 5.46 l at the end of lactation at the 43^{th} week. The persistency after the peak of lactation was 90.7 % (figure 4.1).

On average, daily milk yield was 4.84±2.52 kg, 6.20±2.46 kg and 5.62±2.69 kg, at first (6-16 wks), mid (16-32 wks) and late stage of lactation (32-43 wks), respectively.

4.1.2 Milk flow traits according to the stage of lactation:

On average, machine milk and machine stripping milk was 5.57±2.6 kg, 3±1.67 kg /milking and 0.136±0.01 respectively (Table 4.1). Globally, 67.7% of total milk was obtained in 2 minutes and 83.3% in 3 minutes. The average milk flow rate was 1.11 kg/min and the peak milk flow rate was 1.99 kg/ min. Regarding milk flow durations, the average of main phase, ascending phase, plateau phase, descending phase and total milking was 2.79 ± 0.05 min,1.92 ± 0.05 min, 0.39 ± 0.02 min, 0.93 ± 0.63 min, 6.59 ± 0.09 min respectively (Table 4.1).



Weeks of lactation

Fig 4.1: Changes of milk yield throughout lactation (43 weeks) in lactating dromedary camels (n=22)

The lowest milk yield per milking, (2.83±0.09 kg), was detected at early stage of lactation while camels reached their highest value of milk yield (3.64±0.09 kg) at late stage of lactation ($p<0.0001$). Machine stripping milk increased significantly ($p<0.0001$) to reach the highest value at the late stage of lactation. Average and peak milk flow rate recorded its lowest value at early stage of lactation and showed no significant differences ($p<0.0001$) between mid and late stage of lactation. Decrease of duration time of main phase, ascending phase, plateau phase and total milking yield was observed at mid stage of lactation. At the late stage of lactation camels showed the longest total milking duration ($P<0.0001$). Lowest bimodality percentage values were observed at late stage of lactation while, mid stage presented highest values (Table 4.1).

4.1.3 Milk flow traits according to milking intervals: -

Regarding milking time (Table 4.2), the duration of total milking was significantly longer ($p< 0.0001$) in morning milking (14h interval) compared to evening milking (10h interval). Likewise, the duration of main phase seemed longer in morning milking. A high milking yield was recorded at morning milking while; there was no differences between machine stripping milk (Table 4.2).

Table 4.1. Means of milk flow traits according to the stage of lactation Stage of lactation

Traits	Stage of lactation			
	Early **6-16 weeks**	Mid **16-32 weeks**	Late **32-43weeks**	Means
Yield, kg				
Machine milk	2.83±0.09 [a]	3.22±0.08 [ab]	3.64±0.09 [b]	3.00±1.67
Machine milk in 2 min	1.76±0.8 [a]	2.20±0.07 [b]	2.36±0.08 [b]	2.06±0.04
Machine milk in 3 min	2.33±0.08 [a]	2.78±0.07 [b]	2.96±0.09 [b]	2.52±0.05
Machine stripping milk	0.106±0.015 [a]	0.120±0.014 [a]	0.222±0.016 [b]	0.14±0.01
Time, min				
Main phase	3.145±0.09	2.72±0.08	3.15±0.09	2.79±0.05
Ascending phase	2.03±0.09	1.64±0.08	2.07±0.11	1.92±0.05
plateau phase	0.47±0.03	0.36±0.02	0.40±0.03	0.39±0.02
Descending phase	0.63±0.03	0.73±0.02	0.68±0.02	0.93±0.62
Total milking	6.21±0.15 [a]	5.89±0.12 [a]	8.02±0.15 [b]	6.59±0.09
Flow rate, kg/min				
Average milk flow rate,	0.874±0.037 [a]	1.124±0.032 [b]	1.130±0.038 [b]	1.11±0.02
Peak milk flow rate,	1.72±0.07 [a]	2.153±0.06 [b]	2.21±0.07 [b]	1.99±0.04
Bimodality, %	30.2	33.0	23.4	29.3

Table 4.2. Milk flow parameters and milking traits of dromedaries' camel according to time of milking session.

Traits	Time of milking		
	Morning (06:00)	Evening (16:00)	P. value
Yield, kg			
Machine milk	3.41±0.08[a]	3.06±0.08[b]	0.0006
Machine stripping milk	0.151±0.013	0.149±0.012	0.9085
Machine milk in 2 min	2.13±0.07	2.07±0.06	0.4854
Machine milk in 3 min	2.79±0.07	2.60±0.07	0.5190
Flow rate, kg/min			
Average milk flow rate,	1.05±0.03	1.03±0.03	0.6543
Peak milk flow rate,	2.06±0.06	2.01±0.06	0.4815
Bimodality, %	31.4	27.3	-
Time, min			
Main phase	3.15±0.08	2.86±0.07	0.0038
Ascending phase	2.01±0.8	1.82±0.7	0.0638
plateau phase	0.44±0.03	0.38±0.03	0.1008
Descending phase	0.70±0.02	0.66±0.02	0.1070
Total milking	7.19±0.12 [a]	6.23±0.12 [b]	<0.0001

4.1.4 Milk flow traits according to modality of curve:

Camel's milk flow curves in this study were divided into two groups, camel with bimodal and mono- modal curves (Table 4.3). Bimodality represented 29.3% of the total curves but this type was more common at mid stage of lactation (33%) compared to early (30%) and late (23.4%). Camels with bimodality curves had a higher total milk yield (3.77±0.10 kg/milking), and higher value of milking obtained in three minutes: 3.12±0.09 kg ($p<0.0001$). Stripping milk yield, milking obtained in two minutes and peak milk flow showed lower value in camels with mono – modality curve. Main and descending phase of milking were significantly different ($p<0, 0001$) between two groups while there was no difference in the duration of total milking. Moreover, camels with bimodality curve reached a more than fifth time longer descending phase of milking. Milk yield per milking ($r= 0.17$; $p< 0.01$), peak milk flow ($r=0.16$; $p< 0.01$), average milk flow ($r=0.16$; $p< 0.01$) and the duration of total milk yield ($r= 0.26$; $p< 0.01$) correlated positively with lactation stage.

4.1.5 Correlation between camel's milk flow traits:-

Among different milk flow traits (Table 4.4), Pearson correlation coefficient showed significant ($p< 0.01$) negative relationship between milk flow parameters average and peak milk flow and the duration of certain milking phase (main, plateau and ascending phase). Milk yield per milking was positively related to peak milk flow ($r= 0.74$; $p< 0.01$), average milk flow rate ($r=0.65$; $p< 0.01$), and duration of total milking time ($r=0.88$; $p< 0.01$). Milk yield per milking ($r=0.29$; $p< 0.01$), duration of main phase ($r=0.27$; $p< 0.01$) and duration of descending phase ($r= 0.72$; $p< 0.01$) revealed positive correlation with bimodality of the milk flow curve. Milk yield per milking (r=

0.17; $p < 0.01$), peak milk flow ($r=0.16$; $p < 0.01$), average milk flow ($r=0.16$; $p < 0.01$) and the duration of total milk yield ($r= 0.26$; $p < 0.01$) correlated positively with lactation stage.

Table 4.3. Means for milking traits 'according to milk emission kinetic patterns.

Traits	Milk emission pattern		
	Bimodality	Mono – modality	P. value
Yield, kg			
Machine milk	3.77±0.10 [a]	2.70±006 [b]	<0.0001
Machine stripping milk	0.17±0.02	0.12±0.01	0.0047
Machine milk in 2 min	2.24±0.08	1.97±0.05	0.0069
Machine milk in 3 min	3.12±0.09 [a]	2.27±0.06 [b]	<0.0001
Flow rate, kg/min			
Average milk flow rate,	1.02±0.04	1.07±0.02	0.3167
Peak milk flow rate,	2.15±0.07	1.90±0.06	0.0029
Bimodality, %	29.3	70.7	-
Time, min			
Main phase	3.46±0.09 [a]	2.55±0.06 [b]	<0.0001
Ascending phase	1.85±0.09	1.98±0.06	0.2241
plateau phase	0.45±0.03	0.37±0.2	0.0442
Descending phase	1.16±0.03 [a]	0.20±0.02 [b]	<0.0001
Total milking	6.76±0.15	6.67±0.09	0.6692

Table 4.4. Correlation matrix of camel's milk flow traits (Pearson correlation).

	lactation stage	MMY	PMF	DMPH	DPPH	DASPH	DDPH	MSY	BIMO	AVMF	MY2	MY3	DTMY
lactation stage	1	.168**	.156**	-.016-	-.060-	.010	-.013-	.164**	-.058-	.161**	.169**	.146**	.264**
MMY	.168**	1	.747**	.330**	.082*	.172**	.350**	.306**	.285**	.645**	.807**	.925**	.088**
PMF	.156**	.747**	1	-.126-**	-.193-**	-.122-**	.150**	.167**	.094**	.887**	.868**	.846**	-.140-**
DMPH	-.016-	.330**	-.126-**	1	.189**	.853**	.283**	.010	.256**	-.342-**	-.084-*	.082*	.361**
DPPH	-.060-	.082*	-.193-**	.189**	1	-.186-**	.059	-.026-	.067*	-.098-**	-.029-	.039	.018
DASP	.010	.172**	-.122-**	.853**	-.186-**	1	-.128-**	-.010-	-.046-	-.321-**	-.098-**	-.033-	.348**
DDPH	-.013-	.350**	.150**	.283**	.059	-.128-**	1	.072*	.716**	.005	.054	.259**	.048
MSY	.164**	.306**	.167**	.010	-.026-	-.010-	.072*	1	.077*	.127**	.178**	.208**	.157**
BIMO	-.058-	.285**	.094**	.256**	.067*	-.046-	.716**	.077*	1	-.036-	.082*	.252**	-.009-
AVMF	.161**	.645**	.887**	-.342-**	-.098-**	-.321-**	.005	.127**	-.036-	1	.872**	.795**	-.220-**
MY2	.169**	.807**	.868**	-.084-*	-.029-	-.098-**	.054	.178**	.082*	.872**	1	.939**	-.148-**
MY3	.146**	.925**	.846**	.082*	.039	-.033-	.259**	.208**	.252**	.795**	.939**	1	-.108-**
DTMY	.264**	.088**	-.140-**	.361**	.018	.348**	.048	.157**	-.009-	-.220-**	-.148-**	-.108-**	1

MM: machine milk yield; PMF: peak milk flow; DMPH: duration of main phase; DPPH: duration of plateau phase; DASP: duration of ascending phase; DDPH: duration of descending phase; MSY: milk stripping yield; BIMO: bimodality; AVMF: average milk flow; MY2: milk obtained within two minutes; MY3: milk obtained within three minutes; DTMY: duration of total milk yield.

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed)

4.2: Experiment 2:

4.2.1 General description of udder and teats traits:

The udder length, udder height, udder depth and udder circumference before milking were 43.6±4.9, 106.9±7.7, 43.8±4.6, and 97.1±6.3 cm respectively. The teat length front and rear before milking were 4.85±1.85 cm, 5.09±1.85 cm respectively and teat diameter and distance between teats before milking were 3.43±1.05 cm, 8.92±1.92 cm respectively. The udder depth and udder circumference after milking were 40.5±4.8, 93.7±5.9 cm respectively. The teat length front and rear, teat diameter and distance between teats after milking were 5.42±1.73 cm, 5.32±1.73 cm, 3.06±0.86 cm, 7.96±1.6 cm respectively. Udder length and height did not change before and after milking while significant changes ($p < 0.00l$) in udder depth and circumference were observed (table 4.5). Elsewhere high significant difference ($p < 0.00l$) was observed in front teat length and diameter and distance between teat before and after milking while the rear teat length showed no difference.

4.2.2 Udder and teats measurements during lactation:

Regarding lactation stage (table 4.6), udder depth and circumference showed lowest value at the first stage of lactation and increased up to mid stage of lactation then decreased slightly at the end of lactation. Udder height and udder length showed no significant ($p < 0.00l$) differences along all lactation stage. Teat length front and rear and diameter did not differ along all lactation stage while distance between teats gave the significant highest value at mid stage of lactation. In addition, lactation stage significantly affected udder depth, udder circumference and distance between teat before and after milking ($p < 0.00l$).

Table 4.5 Estimated udder and teats measurement (cm) before and after milking in dromedaries camels.

Traits	NO	Before milking	After milking	P	SE
Udder depth	416	43 ± 4.9 [a]	40.5± 4.8 [b]	< 0.0001	0.469
Udder circumference	416	97.1 ± 6.3 [a]	93.7 ± 5.9 [b]	< 0.0001	0.603
Udder height	416	106.9 ± 7.7	-	-	-
Udder length	416	43.6 ± 4.9	-	-	-
Teat length front	416	4.58 ± 1.85 [a]	5.42 ± 1.73 [b]	< 0.0001	0.121
Teat length rear	416	5.09 ± 1.58	5.32 ± 1.73	0.099	0.176
Teat diameter front	416	3.43 ± 1.05 [a]	3.06 ± 0.86 [b]	< 0.0001	0.095
Distance between teats	416	8.92 ± 1.92 [a]	7.96 ± 1.6 [b]	< 0.0001	0.174

Different letters within a line indicate significant difference ($p \leq 0.0001$)

Table 4.6 Mean udder and teat measurements (cm) before milking and total milk yield (kg) according to stage of lactation in dromedaries' camels.

Parameters	Traits Number				
	N= 77	N= 67	N= 64		
Stage of lactation (week)	10 wk	22 wk	40 wk	Stage [1]	Stage ×BA[2]
Udder height	108.8±7.9	104.5±8.0	107.4±6.4	0.003	-
Udder depth	40.9 ±4.1[a]	46.1±4.2 [b]	44.9 ±3.9 [b]	<0.0001	0.383
Udder length	43.2±4.8	43.7±3.0	44.4 ± 4.8	0.235	-
Udder circumference	95.4±7.8 [a]	99.9±5.3[b]	96.4 ± 4.1 [a]	<0.0001	0.267
Teat length front	5.0±1.9	4.6 ± 1.9	4.9 ± 1.8	0.751	0.617
Teat length rear	5.1±1.8	4.8±1.9	5.1 ± 1.8	0.416	0.935
Teat diameter front	3.4±1.3	3.5±0.9	3.4 ± 0.9	0.933	0.964
Distance between teat	8.8 ± 2.0 [a]	9.6 ±1.8[b]	8.3 ± 1.7 [a]	<0.0001	0.561
Total milk yield	4.9 ± 1.7 [a]	6.01 ± 2.3 [b]	4.2 ± 1.7 [a]	<0.0001	-

4.2.3 Correlation between milk yield and udder traits

Milk yield was positively correlated ($p<0.05$) with udder depth, udder length, circumference, teat length front and distance between teats at mid stage of lactation. While, udder height was negatively correlated with milk yield at mid stage of lactation. Positive correlation was found also between teat length and teat diameter at mid and late stage of lactation ($p<0.0001$), and positive correlation ($p<0.0001$) were found between udder depth and length and circumference at mid and late stage. Significant positive correlation was observed between teat length and teat diameter at all stages of lactation ($p<0.0001$). There was also highly negative correlation between teat length and udder height as well as there was negative correlation between teats parameters and udder height. Significant positive correlation $p\leq0.05$ was observed between udder length, udder depth, udder circumference, teat length and distance between teats at the mid stage of lactation (table 4.7). Teat diameter was highly correlated ($p\leq0.0001$) with teats length in front and rear teats all along the stages of lactation.

4.2.4 Udder typology:-

Cluster analysis of 208 udders and teats measurement (early lactation n = 77, mid lactation n = 67, late lactation n = 64) grouped udders with the similar shape. As a result, three types of udders were identified (fig.4.2): type 1: udders appearing with medium udder height and short udder depth, length and circumference in addition the medium teat length and small teat diameter and short distance between teats. It's corresponding to the smallest udder with the smaller teats; type 2: camels with large udder height, medium udder length, depth and circumference with large teat length and diameter and medium distance between teats. It’s corresponding to medium udder with long teats; type 3: camels having lowest udder with biggest udder length and short teat length with big distance between teats. It’s corresponding to biggest udder with relatively medium teats. Udder depth, circumference, teat diameter and distance between teats differed significantly ($P<0.0001$) among all types. Teat length and total milk yield showed no differences between type 1 and type 2 (table 4.8).

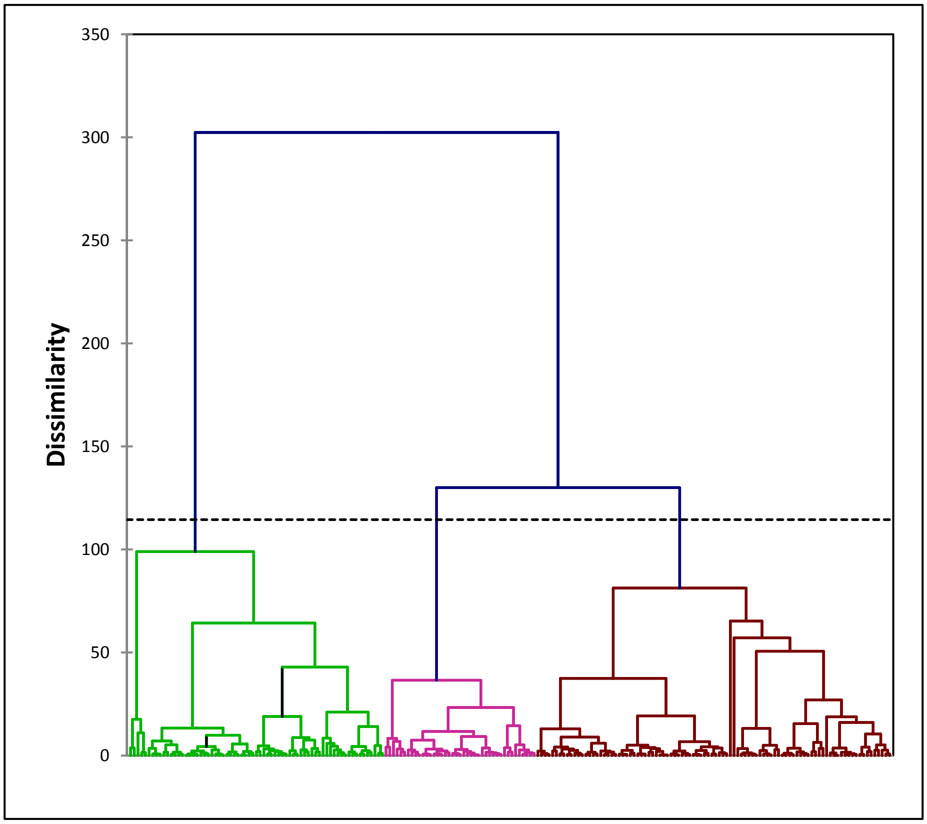


Figure4.2. Dendrogram of hierarchical classification of the 208 udder and teats measurement during three stages showing three type of udders (74.26 % of variances explained)

Table 4.7 Correlation matrix between the different measurements of teats and udder traits and milk yield at mid stage of lactation.

	MYM	MYE	TMY	UH	UD	UL	CP	TLF	TLR	TDF	TDR	DT
MYM		0.7094***	0.9176***	-0.0082	0.2063	0.2444*	0.2942*	0.2952*	0.2455*	0.2531*	0.2253	0.2711*
MYE	0.7094***		0.9310***	-0.0100	0.2555*	0.3460**	0.1913	0.1832	0.1147	0.0716	0.0920	0.3227*
TMY	0.9176***	0.9310***		-0.0099	0.2509*	0.3216*	0.2602*	0.2562*	0.1918	0.1714	0.1685	0.3223*
UH	-0.0082	-0.0100	-0.0099		-0.1570	0.1335	-0.2424*	-0.3838**	-0.3240*	-0.2883*	-0.3449**	-0.0544
UD	0.2063	0.2555*	0.2509*	-0.1570		0.3987**	0.6153***	0.3713**	0.2840*	0.3899**	0.3175*	0.4741***
UL	0.2444*	0.3460**	0.3216*	0.1335	0.3987**		0.2826*	0.0176	0.0170	-0.0810	-0.0119	0.2943*
CP	0.2942*	0.1913	0.2602*	-0.2424	0.6153***	0.2826		0.3062*	0.2156	0.4826***	0.4675***	0.4441***
TLF	0.2952*	0.1832	0.2562*	-0.3838**	0.3713**	0.0176	0.3062*		0.8195***	0.7410***	0.6164***	0.1384
TLR	0.2455*	0.1147	0.1918	-0.3240*	0.2840*	0.0170	0.2156	0.8195***		0.6904***	0.5076***	-0.0139
TDF	0.2531*	0.0716	0.17144	-0.2883*	0.3899**	-0.0810	0.4826***	0.7410***	0.6904***		0.7756***	0.2358
TDR	0.2253	0.0920	0.1685	-0.3449**	0.3175*	-0.0119	0.4675***	0.6164***	0.5076***	0.7756***		0.2191
DT	0.2711*	0.3227	0.3223*	-0.0544	0.4741***	0.2943*	0.4441***	0.1384	-0.0139	0.2358	0.2191	

UH: udder height; UD: udder depth; UL: udder length; CP: udder circumference; TLF: teat length front; TLR: teat length rear; TDF: teat diameter front; TDR: teat diameter rear; DT: distance between teat; TMY: total milk yield: MYE: milk yield evening; MYM: milk yield morning * $P \leq 0.05$; ** $P \leq 0.005$; *** $P \leq 0.0001$

Table 4.8 udder and teat measurements (cm) and daily milk yield (kg/d) related with different udder types

Traits	Udder type			
	Number	Type 1	Type 2	Type 3
Udder height	208	106.8±5.6 [ab]	108.5±7.8 [a]	103.0±7.3 [b]
Udder depth before milking	208	39.6 ±4.4[a]	44.3±4.2 [b]	45.3±4.7 [c]
Udder length	208	40.3±7.6 [a]	44.2±4.3 [b]	44.4±3.3 [b]
Udder circumference before milking	208	89.8±7.7 [a]	97.7±5.2 [b]	100.8±4.2 [c]
Teat length front	208	4.9 ±2.3 [a]	7.0 ± 2.0 [b]	4.2±1.1 [a]
Teat length rear	208	4.9 ± 1.7 [a]	7.5 ± 1.8 [b]	4.4 ± 1.2 [a]
Teat diameter front	208	2.6 ± 0.8 [a]	3.3 ± 0.8 [b]	4.5± 1.0 [c]
Distance between teats	208	6.6 ± 1.2 [a]	9.1 ± 1.7 [b]	10.0 ± 1.7 [c]
Total milk yield	208	4.4 ± 1.4 [a]	4.9 ± 1.8 [a]	6.0 ± 2.7 [b]

Means bearing different superscripts with rows are significantly ($p<0.01$) differents

4.2.5 Udder and teat shapes frequencies: -

It may be observed from (Table 4.9), that a great variation existed in the morphology of udders and teats in (AL-Awarik) lactating camels. The results showed among the different udder shapes, globular shape was very common with a percentage of 47.22 %, 46.67% followed by pendulous and pear shapes at the first and late stage of lactation respectively. Similarly among the different shape of teats, cylindrical teats were more frequent than other shapes with a percentage of 43.06 %, 61.67% at the first and late stage of lactation respectively followed by funnel and bottle teat shapes. The percentage occurrence of funnel shape were 36.11%, 28.33% and the bottle shape were 20.83% at the first and late stage of lactation respectively.

4.2.6 Daily milk yield in camels with various udder and teat shape:

Effects of udder and teats shapes on morning, evening and total milk yield were evaluated at first and late stage of lactation. The means of morning, evening and total milk yield with their standard deviation according to udder and teat shapes are given in tables (4.10, 4.11).

Udder shapes significantly affected total milk yield ($p \leq 0.05$) but did not affect morning and evening milk yield ($p \leq 0.05$) at first stage of lactation. Camel with Pear-shaped udder had significantly ($p \leq 0.05$) higher milk yield of 5.64±0.39kg following by globular and pendulous udder shape. Morning, evening and total milk yield were not affected by teat shape ($p \leq 0.05$) at first stage of lactation. However, small and non-significant ($p \leq 0.05$) differences in level of morning and total milk yield existed at late stage of lactation.

Table 4.9. Frequencies and percentage of different udder and teat shapes of dairy dromedary camels at first and late lactation.

Parameters	First lactation		Late lactation	
	N	%	N	%
Udder shape				
Globular	34	47.22	28	46.67
Pear	17	23.61	13	21.67
Pendulous	21	29.17	19	31.67
Total	72	100	60	100
Teat shape				
Bottle	15	20.83	6	10
Cylindrical	31	43.06	37	61.67
Funnel	26	36.11	17	28.33
Total	72	100	60	100

Table 4.10. Daily milk yield (kg) in experimental camels with various udder and teat shapes at first lactation.

Parameters	AM.yield	PM. yield	Total milk	SEM
Udder shape				
Globular	2.12±0.14	2.61±0.17	4.71±0.28ab	0.472
Pear	2.35±0.18	3.19±0.28	5.64±0.39a	0.236
Pendulous	2.40±0.20	2.94±0.23	4.41±0.36b	0.291
C.V, %	36.83	36.25	33.12	-
P<	0.472	0.147	0.047	-
Teat shape front				
Bottle	2.37±0.22	2.98±0.25	5.35±0.41	0.048
Cylindrical	2.26±0.15	2.63±0.18	4.80±0.29	0.058
Funnel	2.19±0.17	2.49±0.19	4.58±0.32	0.057
C.V, %	37.13	36.16	36.16	-
P<	0.812	0.296	0.296	-

Table 4.11. Daily milk yield (kg) in experimental camels with various udder and teat shapes at late lactation.

Parameters	AM.yield	PM.yield	Total milk	SEM
Udder shape				
Globular	2.04±0.15	2.49±0.20	4.16±0.33	0.065
Pear	2.03±0.19	2.40±0.30	4.15±0.49	0.054
Pendulous	1.75 ±0.20	2.48±0.24	4.09±0.41	0.060
C.V, %	36.85	43.48	42.87	-
P<	0.466	0.968	0.988	-
Teat shape front				
Bottle	1.66±0.28	2.33±0.43	4.00±0.40	0.039
Cylindrical	2.14±0.12	2.59±0.17	4.45± 0.28	0.063
Funnel	1.65±0.19	2.25±0.26	3.51 ±0.42	0.059
C.V, %	30.74	40.91	41.25	-
P<	0.060 (tendency)	0. 516	0.103 (tendency)	-

Otherwise, milk yield and evening milk yield were found nearly similar for pendulous, pear and globular shapes at late stage of lactation. In addition, no significant effect ($p \leq 0.05$) was observed for teat shapes on morning milk yield at late stage of lactation.

4.2.7 Udder measurements according to udder shape: -

The means with standard deviation for various udder measurements according to the udder shapes in first and late stage of lactation are presented in table 4.12. Udder depth, length and circumference in different udder shapes at first and late stage of lactation ranged from 40.14±0.66 to 46.36±0.71cm, 42.05±0.97 to 46.89 ±0.90 and 94.31±1.01 to 97.88±0.64, respectively. Thus, the udder measurements in camels were low in globular shaped udder compared to other shapes. No significant differences ($p \leq 0.05$) were observed between udders shape and udder measurements for first stage of lactation. While, significant differences ($p \leq 0.05$) were observed in udder length between pear and globular shaped udder; between pear and pendulous shaped udders. On the other hand, no significant differences ($p \leq 0.05$) were found between globular and pendulous shaped udders. In addition, no statistical significantly difference ($p \leq 0.05$) was observed between udder depth and circumference for udder shaped at late stage of lactation.

4.2.8 Teats measurements according to udder shape: -

Teat measurements according to udder shapes in first and late stage of lactation were presented in table (4.13). There was a great variation in teat length at first and late stage of lactation in front and rear quarter ranging from 3.70±0.25 cm to 5.80± 0.45 cm and 4.50 ±0.22 cm to5.89 ±0.51cm respectively. While the average of teat diameter and distance of teat with various udder shapes ranging from 2.94 ±0.18 cm to 4.01±0.45 cm and

7.88±0.35 cm to 9.62±0.39 cm respectively. At the first stage of lactation teat length, diameter and distance between teats were lower in globular udders shape compared to other types of udders. Nevertheless, there was no significant differences $p \leq 0.05$ between teats measurements in pear and pendulous udders shape except for front distance between teats which was significantly different ($p \leq 0.05$).

Furthermore, significant differences $p \leq 0.05$ were observed between rear teat length and distance between teats between pear and pendulous udders shape at late stage of lactation. Teat length was more in pear udder compared to other udders. Otherwise, pendulous udder shaped has highest diameters and distances between teats. No significant differences (p≤o.o5) were observed between front teat length and front teat diameters for various udder shapes.

Table 4.12. Various udder measurements (cm) in dromedary camels according to the udder shape (first and late lactation).

Udder shape	UD		UL		CP	
	Mean+SD	C.V,%	Mean+SD	C.V, %	Mean+SD	C.V, %
First lactation						
Globular	40.14±0.66	9.60	42.05±0.97	13.45	94.31±1.01	6.23
Pear	42.14±1.13	12.26	44.34±0.72	7.48	95.40±2.52	12.13
Pendulous	41.00±0.80	8.04	43.53±1.08	10.23	97.30±1.58	6.71
Late lactation						
Globular	44.29±0.80	9.58	43.45^{b}±0.80	9.75	96.02±0.67	3.70
Pear	46.36±0.71	6.70	46.89^{a}±0.90	8.41	96.11±1.30	5.90
Pendulous	44.45±1.06	8.94	43.14^{b}±1.67	14.49	97.88±0.64	2.45

UD = Udder depth; UL = Udder length; CP = Udder circumference

Table 4.13. Various teat measurements (cm) in dromedary camels according to the udder shapes (first and late lactation).

Teat shape	TLF		TLR		TDF		DT	
	Mean+SD	C.V,%	Mean+SD	C.V, %	Mean+SD	C.V,%	Mean+SD	C.V, %
First lactation								
Globular	4.32^{b}±0.24	32.85	4.50^{b}±0.22	28.63	2.94^{ab}±0.18	35.01	8.40^{b}±0.32	22.08
Pear	5.80^{a}± 0.45	35.76	5.74^{a}± 0.41	33.05	3.79^{a}± 0.18	21.74	9.62^{a}±0.39	18.77
Pendulous	5.70^{a}± 0.48	34.93	5.86^{a}±0.55	38.45	4.01^{b}±0.45	46.11	8.52^{a}±0.56	27.24
Late lactation								
Globular	3.70±0.25	27.25	4.95^{ab}±0.29	30.56	3.25± 0.12	19.97	8.30^{ab}±0.35	22.31
Pear	5.34±0.48	39.38	5.89^{a}±0.51	37.72	3.53±0.25	30.79	7.88^{b}±0.35	19.27
Pendulous	4.65±0.57	45.91	4.57^{b}± 0.42	34.60	3.70± 0.32	32.12	9.09^{a}±0.44	18.23

TLF: teat length front; TLR: teat length rear; TDF: teat diameter front; DT: distance between teat

4.2.9 The Correlations between udder and teat measurements and daily milk yield: -

Correlation coefficient observed between various udder and teat measurements and daily milk yield in first and late stage of lactation are shown in table (4.14) and (4.15).

Positive and significant ($p \leq 0.05$) correlations were observed between udder depth, teat length rear and distance between teats and daily milk yield at first stage of lactation. Similarly, udder depth and circumference and distance between teats correlated positively with daily milk yields at late stage. Significant ($p \leq 0.05$) and a positive correlation observed between udder length and depth.

There were great positive correlation observed between various teat measurements viz.., teat length front and rear, teat diameter and distance between teats were also positive and significant ($p \leq 0.05$) to highly significant ($p \leq 0.0001$) at first and late stage of lactation.

Table 4.14. Correlations between udder and teat measurements and daily milk yield in dairy dromedary camels (first lactation)

	TMY	UD	UL	CP	TLF	TLR	TDF	DT
TMY		0.398	0.113	0.172	0.178	0.242	0.190	0.484
		0.0255	0.3512	0.1526	0.1397	0.0431	0.1174	0.0453
UD	0.3982		0.30506	0.08054	0.31426	0.26794	0.07935	0.06237
	0.0255		0.0092	0.5012	0.0072	0.0229	0.5107	0.6027
UL	0.11311	0.30506		0.54157	-0.0731	0.04968	0.47255	0.24562
	0.3512	0.0092		<.0001	0.541	0.6786	<.0001	0.0376
CP	0.17280	0.08054	0.54157		-0.038	0.12737	0.55981	0.33535
	0.1526	0.5012	<.0001		0.7488	0.2863	<.0001	0.33535
TLF	0.17834	0.31426	-0.073	-0.0384		0.93716	0.39470	0.08653
	0.1397	0.0072	0.5414	0.7488		<.0001	0.0007	0.4698
TLR	0.24247	0.26794	0.04968	0.12737	0.93716		0.48037	0.14486
	0.0431	0.0229	0.6786	0.2863	<.0001		<.0001	0.2247
TDF	0.19023	0.07935	0.47255	0.55981	0.39470	0.48037		0.40997
	0.1174	0.5107	<.0001	<.0001	0.0007	<.0001		0.0004
DT	0.48496	0.06237	0.24562	0.33535	0.08653	0.14486	0.40997	
	0.0453	0.6027	0.0376	0.0040	0.4698	0.2247	0.0004	

TMY: total milk yield: UD: udder depth; UL: udder length; CP: udder circumference; TLF: teat length front; TLR: teat length rear; TDF: teat diameter front; TDR: teat diameter rear; DT: distance between teat

Table 4.15. Correlations between udder and teat measurements and daily milk yield in dairy dromedary camels (late lactation)

	TMY	UD	UL	CP	TLF	TLR	TDF	DT
TMY		0.42251	0.07361	0.28957	0.21927	0.14830	0.08029	0.6592
		0.0322	0.5697	0.0224	0.0868	0.2500	0.5350	0.03973
UD	0.42251		0.55115	0.22164	0.29711	0.23174	0.27039	-0.0186
	0.0322		<.0001	0.0834	0.0190	0.0699	0.0335	0.8856
UL	0.07361	0.55115		0.18480	0.06914	0.10504	0.20630	-0.2250
	0.5697	<.0001		0.1505	0.5933	0.4165	0.1077	0.0787
CP	0.28957	0.22164	0.18480		0.19093	0.29380	0.39211	0.08133
	0.0224	0.0834	0.1505		0.1371	0.0205	0.0016	0.5297
TLF	0.21927	0.29711	0.06914	0.19093		0.79581	0.61828	0.31591
	0.0868	0.0190	0.5933	0.1371		<.0001	<.0001	0.0124
TLR	0.14830	0.23174	0.10504	0.29380	0.79581		0.56578	0.13274
	0.2500	0.0699	0.4165	0.0205	<.0001		<.0001	0.3037
TDF	0.08029	0.27039	0.20630	0.39211	0.61828	0.56578		0.41180
	0.5350	0.0335	0.1077	0.0016	<.0001	<.0001		0.0009
DT	0.6592	-0.0186	-0.2250	0.08133	0.31591	0.13274	0.41180	
	0.03973	0.8856	0.0787	0.5297	0.0124	0.3037	0.0009	

TMY: total milk yield: UD: udder depth; UL: udder length; CP: udder circumference; TLF: teat length front; TLR: teat length rear; TDF: teat diameter front; TDR: teat diameter rear; DT: distance between teat

Chapter Five
Discussion

CHAPTER FIVE
Discussion

Milk flow parameters and duration in lactating camels related to milkability were analyzed. The overall mean of average and peak milk flow in the study was relatively close to the finding of Atigui *et al*., (2014b) who recorded 1.15 k/min and 2.46 kg/min for average and peak milk flow, respectively. The discrepancy between study results with those obtained by Atigui *et al.* (2014b) might be attributed to the difference between milking intervals used in each experiment. However, these results were similar with those previously reported by Ayadi *et al.* (2018) in dairy dromedary camels. On the other hand, it was lower than Edwards et al., (2014) who reported 1.75 kg/min for average and 3.27 kg/min for maximum milk flow rate in dairy cow. Otherwise all these parameters were quite higher than those found by Bava *et al.*, (2007) in Italian buffalo.

Obvious differences in milk flow parameters were detected in the present study between milking time, stage of lactation and bimodality compared with normal modality curves.

Over 43 weeks in lactation, turned out that stage of lactation significantly and positively affected milk yield, milk flow rate and duration of total milk yield. Same finding was stated by Aydin *et al.*, (2008) in Brown Swiss cows. In contrast, Antalik *et al.*, (2011) reported that Slovak Simmental dairy cow reached its highest average and maximum milk flow rate at second half of lactation. Compared to cow, camel produced milk up to 18^{th} month of lactation with average of 12.5 months (Musaad *et al* 2013a). Similarly, Edward *et al.*, (2014) reported an increase in the cisternal fraction (proportion of the total milk held in the cistern) as lactation stage increased in cow. This was supported by the results of the present study where the percentage of milk harvested in the first 2 min, 3 min and total milking yields per milking increased as lactation progressed. Duration of total milking was significantly longer in late stage of lactation. In cow, Bruckmaier and Blum (1998) explained the increasing of milking time at the late stage of lactation as the results of reduced volume of milk stored in the udder at the end of lactation, which needs more stimulatory requirement to induce milk ejection response, and which usually takes longer to occur. Conversely, more milk yielded by experimental camels as lactation progressed, resulting in extra time needed to empty the udder. Moreover, the stage of lactation mainly affects the duration of total milking. While, the main, ascending and descending phase were not affected, this explains the effect of lactation stage on lag time and over milking time. Bruckmaier and Hilger (2001) reported the longest duration of total milking in late stage resulting by the deletion of milk ejection in late lactation. For this reason, pre-milking stimulation is even more important especially during this period of milking. Furthermore, especially in large scale camel farm camels must be selected with the best maternal behavior (less aggressive, accepting easily udder contact by hand and releasing milk (Marnet *et al.*, 2015) to ensure parlor milking efficiency and rapid process for all stage of milking. As such, Atigui *et al.*, (2014a) stated average and peak milk flow rates were significantly lowered when unusual noises were heard from the beginning of milking. In the present study the variation in the duration of milking time through stage of lactation agreed with Tancin et al., (2006) who reported that milking duration varied among milk yield and milk flow rate, which varies during different phases of a milking during stage of lactation in dairy cow.

The occurrence of bimodal milk flow in the study (29.3%) was of lower value compared to 41.9 % reported by Atigui *et al.,* (2014b). This reduction could be due to the milking interval and adaptation of camel for milking machine (Table 4.3). Thomas et al., (2004) and Sandrucci *et al*., (2005) reported that the bimodality was affected by pre-milking operations. So, in this present study, the low proportion of bimodal milk flow was linked with longest length of main milking phase and descending phase. Milk yield, duration of main phase and peak milk flow were found higher in bimodal groups which is similar to the observations of Di Palo *et al*., (2007) in buffaloes which had similar udder cistern size and almost 95% of the milk stored in alveolar compartment, close to camel udder capacity (Costa *et al*., 2004; Thomas *et al*.,2004). Moreover, Ambord *et al.,* (2010) in Mediterranean buffalos stated that the increase of udder pre-stimulation reduced bimodality occurrence. Length of main milking phase was higher in camel with bimodality curves *vs* the normal curves. This was due to longest descending phases. This could be a better indication in order to improve the milking routine, to avoid dropping in milk with prolonged plateau phase with rapidly descending phase, and finally to achieve highly parlor milking efficiency.

Milking interval mainly affected total milk yield, duration of main phase and total milk yield per milking (Table 4.2). Similar results were reported by Fahim *et al.,* (2017) who reported that morning session was more time consuming due to higher yield in this session compared to afternoon and evening sessions. In the same line, Tancin *et al., (*2003) and Wagner et al., (2002) found that differences in the duration of milking was a consequence of the variation in milk yield between morning and evening in dairy cow. Although significant difference in milk production occurred, there was no effect of morning and evening milking on peak and average flow in this study, contrary to Cho *et al*., (2004) who stated the longest duration of milk flow with milking interval over than 13.5hrs. The positive correlation with milk yield and duration of total milking time in the current results explain this variation in the duration of total milking.

The milk yield of the camel varies greatly depending on several factors such as breed, management, season and regions. Milk yield produced per day and per lactation period vary between individuals. the results of the study were similar to these reported data of Jemmali *et al.,* (2016) and Ishag *et al.,* (2017) in Tunisian and Sudanese intensive systems, but it was higher than those of Osman et al., (2015) who showed that most of she-camels producing from 2 to 3 l milk/day during the lactation period of 10 month in Sudanese pastoral camels. Peak production in this study was reached in the 26th week of lactation with an average of 8.66 l/day (figure 4.1). Similar plateau was observed by Musaad *et al*., (2013a) between the fifth and the eighth months of lactation for Saudi camels followed by a decrease from the 47th week to the end of lactation. Aziz *et al*., (2017) reported 7.24 l at the peak in 28th weeks of lactation. On contrary, the peak was observed earlier, between 9 and 19 weeks in Ethiopian camels (Bekele *et al.,* 2002)

Negative correlations occurred between milk flow parameters and the duration of certain milking phases. But the positive correlations between milk yield per milking with peak milk flow, average milk flow rate and duration of total milking time. This finding maybe a great guide and motivation to select and improve camels with high milk flow traits to achieve highly camel parlor milking efficiency.

Bimodality was positively correlated with duration of the decline phase and negatively with duration of the ascending phase. Similar results were recorded by Sandrucci *et al.*, (2007) in Italian Holstein-Friesian dairy cow. Therefore, bimodality mainly affected milking time, thus the efficiency of milking machine. Tow peak milk flows presented by bimodality led to highly negative correlation with average milk flow.

Morphological characterizations of udder and teats in dairy camel have taken a deal of attention and to its relationship with milk production, machine milkability and manageability. There was a great variation in udder and teat size and length in camel which is attributed to many factors such as camel type, stage of lactation, parity, and udder health (Zayeed *et al.*, 1991). Udder measurements reported in (Table 4.5) were higher than those reported by Atiguiet al (2016) for Maghrebi camel's intensive system and Eisa *et al.,* (2010) for Arabi-Lahwee camels in semi intensive system. Our camels have particularly large udder length and small udder depth compared to values reported by Ayadi *et al*., (2015) and this variations may be attributed to camel breed. Moreover, udder and teats measurements at late stage of lactation are close to the values reported by Ayadi *et al.,* (2013)

Teats measurement reported in the present study before milking showed lower values than those reported by Atigui *et al.*, (2016) for Maghrebi camels managed in intensive system in Tunisia, and teat diameters have lower values in comparison to the results reported by Nagy *et al.,* (2015). The diameter slightly decreased in its size during and after milking in agreement with Nagy *et al.,* (2015). Udder depth and circumference showed significant differences before and after milking as well as front teat length, diameter and distance between teats while there is no significant change for rear teat length which had higher values than the front similarly to result obtained by Nagy *et al.*, (2015). Those authors reported that the size of teats decreased after milking, and changes in front quarter were more obvious than in the back. This is the reason of more milk received from the back–quarter (Yagil, 1985). Eisa *et al.*, (2010) reported similar results with significant decrease ($p \leq 0.01$) for teat length, diameter, udder depth and circumference. Moreover, Juhasz *et al*., (2008) stated that the teat underwent significant size changes during milking and the length increased by 50 % in intensive machine milked camels.

For high camel machine milking efficiency Atigui *et al.*, (2015) recommended some of clusters liner parameters to avoid too much elongated teats during milking. Szencziova Iveta *et al*., (2013) reported various changes in teats morphology in the dairy cow caused by milking machine and recommended ultrasonography method for accurate investigations. From their side, Tilki *et al.,* (2005b) reported no significant correlation between udder heights before and after milking while they found significant decrease in distance between front teat and significant decrease in teat length in brown Swiss cows.

Udder depth and circumference were significantly changed during lactation and reached their higher values at the mid stage of lactation in the present study. This is due to the increasing of milk production and cisternal size corresponding in camel to the lactation peak which occurs as a plateau between the 3^{th} and 5^{th} month of lactation (Musaad *et al.,* 2013a). Both in camel (Atigui, 2016) and cow (Caja *et al.,* 2004) larger milk production is related to a bigger udder size. Otherwise, there are no significant change for udder height and length in accordance with the results obtained by Martinez *et al.*, (2011) in Suffolk sheep. There were no significant changes in the teat traits except the distance between teats during lactation contrary to the finding reported by Sadeghi *et al.,* (2016) in Indian goats. There are several other factors that influence udder morphology, particularly genotype, lactation stage, lactation rank and breeding system (Milerski *et al.,* 2006). A few authors who have studied the modification occurring in the udder and teats throughout lactation period in camels. Yet, these studies are essential to improve camel dairy production.

Cluster analysis identified three types of udder according to udder and teats measurement. These 3 types can be observed within the same breed reflecting the high within-breed variability as reported by Eisa *et al.,* (2010) in Arabi-lahwee camels in Eastern Sudan. These testify also the potential of genetic selection within a specific breed. From their part, Ishag *et al.,* (2011) classified Sudanese camels into 10 types based to udder and teats size (large, medium, rudimentary). Sandor *et al.* (2006) reported that udder type in sheep had only small effect on milk yield and linked its importance to machine milking. Such phenotypic description can be useful for selected lactating camels and set appropriate parameters of milking machine.

Relationships among udder and teats and daily milk yield indicated that selection of lactating camels with greater distance between teat, greater udder depth and circumference would result in higher milk production. Similar finding was also reported by Ayadi *et al.,* (2013) and Eisa *et al.,* (2010). Prasad et al (2010) reported also positive correlation between udder measurements and milk yield in buffaloes. Positive correlation was also observed between teat length and teat diameter reflecting that only one single teat measurement could be included in the selection schemes.

Positive correlation between inter-teats distance, teat diameter and udder circumference indicated positive relationship of teat dimension with udder capacity. The high positive correlations among teat measurement indicated the importance of the teats in the selection of lactating camels. The correlations of teat length, teat diameter, distance between teats, udder depth, udder circumference and milk yield with udder height were all negative that means highest udder corresponding with small udder.

In this study most of examined camels had globular udder shape. In contrast the pear udder shape was very little. The results in the present study were in agreement with Ayadi *et al.* (2016) who also report the majority of the dairy Arabian camels had globular udder shape.

The majority and percentage of cylindrical shaped teats observed in the present study were in agreement with Nagy *et al.,* (2015) in intensive camel milk production in the UAE. Otherwise in agreement with some authors who reported the majority of Murrah buffaloes had cylindrical shaped teats (Prasad *et al.,* 2010; Thomas *et al.,* 2004 and Bainwad *et al.,* 2007). In contrast the percentage of cylindrical shape were more than that reported by Ayadi *et al.,* (2016) who states the funnel shape as the more frequent one with 63.2% and 58.7% for front and rear teats.

There were significant differences $p \leq 0.05$ between various udder shapes and total milk yield clearly shown at first stage of lactation. Same finding were reported by Tag El-Dein *et al.,* (2011) the udder shape appeared to have marked effects $p \leq 0.01$ on milk yield in milking time and average milk flow rate in Friesian cows. Otherwise morning and evening milk yield showed no significance, this explained the association of amount of milk production to illustrate udder shape and measurements with the confirmation of no relation was found at late stage of lactation between udder shape and milk yield. Camel with Pear udder shaped yielded more than other shapes at first stage of lactation. However, regarding the effect of udder shape on milk yield Prasad et al (2010); Bhuiyan *et al*., (2004) found a higher yield in bowel shaped udders in cows. The low frequency of pendulous udders in camels was probably due to previous infection of mastitis or injuries occurred lately and this is some of the reasons for camel culling in intensive systems. Similarly, Ayadi et al., (2016) stated that pendulous udder was non preferable by the farmer for their non –suitability for machine milking and calf stripping.

Chapter Six

Conclusion and Recommendations

CHAPTER SIX
Conclusions and Recommendations

6.1 The Conclusions: -

Milk flow characteristics and lactational performances changed as lactation progressed, with duration time longest in late lactation. The milk yield and the duration of milk flow curve were different according to milking intervals, likely bimodality was correlated with less milking efficiency. Milk flow traits may be a great procedure for milk performance evaluation. Direct selection of dairy camel consistent with rapid flow rate and constrained machine time could be envisaged for dairy camel. For the establishment of optimum selection criteria on these traits**.**

The present study confirmed that the udder measurements were the main selection markers for camel milkability. Udder scoring could be very useful in genetic selection program for improving machine milking. However, the links with udder health is necessary in further studies especially by studying the impact of mastitis incidence which is main cause of culling in dairy camels.

In conclusion it's clear that teat and udder shapes and dimensions have relationship and were related to yield and milking efficiency in lactating camels. There for these traits must be considered accordingly while selecting dairy camels.

6.2 **Recommendations:-**

- Selection regarding high yielder camel together with machine milking ability and adaptability to the milking parlor. However, the camels must be characterized by (less aggressive, accepting easily udder contact by hand and releasing milk…).

- The lactating camels must be chosen according to the formal characteristics of the udder and teats because they are directly related to the milking machine and the quality of the milk production.

- It is recommended to exclude camels with low milk flow rate and longer milking duration as an important first step for selecting camel for ease of milking machine and raising production efficiency.

- Improvement of milking machines for camels, must be taken into consideration with the great variations in shape and size of udders and teats.

- The best teats shape is cylindrical teats followed by funnel teats and irregular shaped teats or pendulous shape need to be eliminated by selection

-To achieve high machine milking efficiency with regards to actual Milking Time, must take into account milking machine settings. Adjustment of Vacuum Pressure, Pulsation Rate and Pulsation Ratio.

- Application of pre- stimulation of lactating camel udder is one of the most effective ways to increase milk flow rate and reduce the proportion of bimodality curve.

- There is an urgent need for genetic improvement programs of camels to raise milk productivity, accompanied by all udder and teats characteristics linked with milk yield.

- Uniformly udder shaped, well established teats, medium long teats, and suitable teat diameter with a correct position are recommended. This udder is good for milking machine and the cups are well attachable, the milking will be smooth at the same time.

- Regular adjustment of machine settlings: Modifications of parameters of milking machine settlings have to be done because of the changing of udder measurements and milk flow parameters during lactation.

- It is recommended to conduct extensive studies on the effects of milking machine systems on the udder health with regard to somatic cells a count.

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Appendixes

Appendix

Photo 1: Vessel in the form of recumbent camel with jugs, 250 BC-224 AD. Source: Brooklyn museum, United States, New York. (Wikipedia).

Photo 2: swelling and milk flow after udder stimulation of lactating camels, field study, camel parlor (Al-kharj, Musaad, 2016).

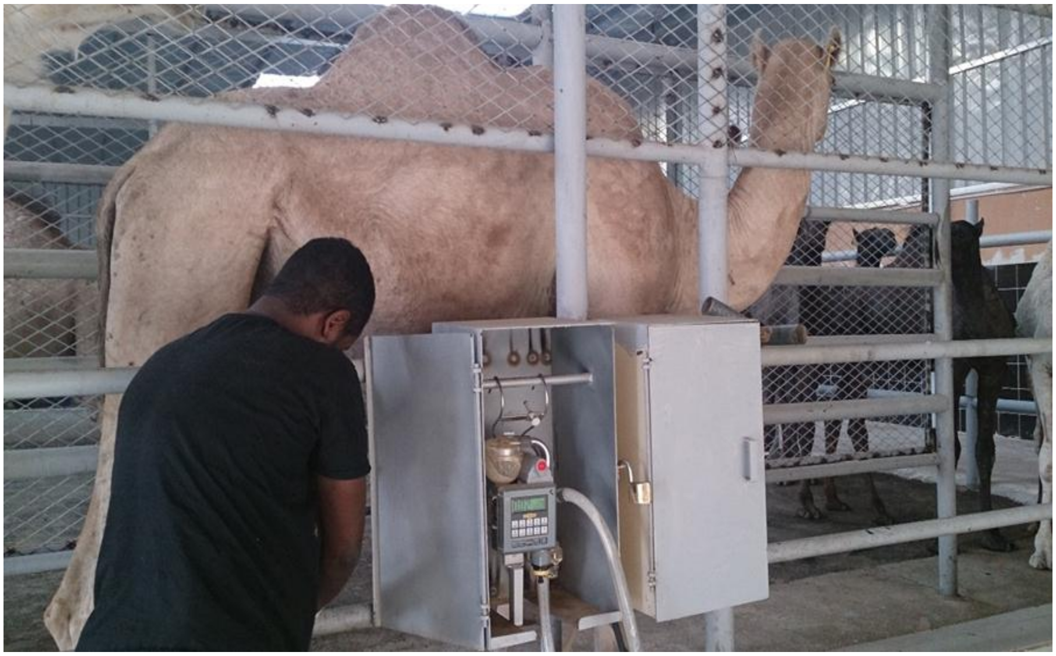

Photo 3: stimulation of the camel's udder before clusters attachments. (Musaad. A.M, 2016)

Photo 4: Al- Turath Agriculure Improvement Company. Camel's parlor. Field study by (musaad A.M, 2015)

Photo 5: Lactocorder Datapack in its read/write station.


Photo 6: determination of the udder measurements.


Photo 7: pendulous udder shape, not suitable for cluster attachments.