PROPERTIES OF MILK POWDER MADE FROM THE MILK
OF COW, GOAT AND CAMEL

by

El- Sara Tag El- Sir AbdAlmageed


Faculty of Agriculture

Umdurman Islamic University

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SUPERVISOR

Prof. El Gasim Ali El Gasim

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

FACULTY OF AGRICULTURE

UNIVERSITY OF KHARTOUM

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بسم الله الرحمن الرحيم

أクラブبكم الله مرفقاً

لا يزال يقرئ البيت 66
DEDICATION

To my father who has implanted in me the love of learning and gave me maximum and endless help and support;

To my mother who taught me the writing of the alphabet, surrounded me with her love and tenderness;

To my brothers and sisters who blessed me to achieve this work;

Finally to my dear friends

Love and respect

El- sara
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Thanks to Allah the most Gracious and merciful for helping me going through and finishing this work.

I wish to express my deepest gratitude and sincere thanks to my supervisor, Professor El gasim Ali El gasim for his kindness, continuous interest, helpful encouragement, constructive criticism and supervision throughout the progress of this study.

My deepest thanks are due to Dr. Iffate Salih who gave me some advices and Abu – baker Abdalla who assisted me when I need it.

Last, but not least, my thanks are due to my friends and colleagues, for their helpful gesture and friendly attitude during this study.
ABSTRACT: A completely randomized experiment was used to assess the physicochemical properties of milk powder produced from the milk of camels, cows and goats raised in farms around Khartoum state. Collected milk samples were transferred immediately to the Industrial Research and Consultancy Center, filtered and divided into two unequal portions. The small portion was refrigerated and used for later analysis; the other portion of the milk was concentrated to 45 – 50% total solids and dried in a spray drier. The proximate composition lactose, total solid, pH, titratable acidity, specific gravity and sensory evaluation were determined in both fresh milk and the milk powder made from it. In addition solubility index, peroxide value (PV) and yield were determined in milk powder samples. Proximate composition results indicated that species had significant effects ($P \leq 0.05$) on protein, fat, moisture, ash, total solid and specific gravity. The titratable acidity of camels milk was significantly higher ($P \leq 0.05$) than that of goat’s and cow’s fresh milk. The highest ($P \leq 0.05$) and the lowest ($P \leq 0.05$) lactose content were found in the goat and camel milk respectively. The same trend continue for the proximate analysis of milk powder obtained from the three
species under study. The protein and fat contents of milk powder differed significantly ($P \leq 0.05$), with the highest value reported for goats milk powder. Milk powder from the three species had similar ($p \geq 0.05$) titratable acidity and solubility index. Camels milk powder had significantly higher ($P \leq 0.05$) PV than either cows or goats milk powder. Among the three species investigated cow's milk gave the highest yield ($P \leq 0.05$). For all the sensory parameters measured, except viscosity, the panelist rated camel's milk powder lower than that from goats and cow. Yield and sensorially wise cow’s milk powder was superior to that of goat or camel.
خصائص لبن البوذمة المصنع من لبن البقر. الماعز والابل

أطروحة ماجستير

السارة تاج السر

مستخلص الأطروحة: تم استخدام تجربة تامة العشوائية لتقييم الخصائص الفيزيوكيميائية للبن البوذمة المصنع من لبن البقر، الأبقار والماعز المربى في مزارع حول مدينة الخرطوم. نقلت عينات اللبن المجمعة فورا إلى مركز البحوث والاستشارات الصناعية، ثم صفيت وتم تقييمها إلى جزءين تم تبريد الجزء الأصغر لإجراء التحليل لاحقا. أما الجزء الآخر فقد تم تركيزه إلى 45 - 50% مواد صلبة وصفيت في المجفف الرذادي. تم تحديد التحليل الكيميائي التقريبي، اللاكتوز، المواد الصلبة، الأنس الهيدروجيني، الحموضة، الكثافة النوعية والتقييم الحسي في كل من اللبن الطازج و لبن البوذمة المصنع منه. إضافة إلى ذلك فقد تم تحديد مؤشر الذائبة، رقم البيروكسيد والعائد في لبن البوذمة. أوضح النتائج أن لنوع الحيوان تأثير (P ≤ 0.05) على نسبة البروتين، الدهن، الرطوبة، الرماد، المواد الصلبة الكلية والكثافة النوعية. إحتوى لبن البقر على حموضة كليه أعلى (P ≤ 0.05) من نظيره في الماعز والأبقار. سجل أعلى (P ≤ 0.05) وآدنى (0.05 ≤ P) محتوى لللاكتوز في لبن الماعز والابل على التوالي. واستمرت هذه الظاهرة في نتائج التحليل التقتريبي للبن البوذمة المتحصل عليه من الثلاث أنواع من الحيوانات تحت التجربة. إختلفت معنويًا (P ≤ 0.05) محتويات البروتين، الدهن للبن البوذمة حيث سجلت أعلى قيمة للبن بودرة اليمام. كانت الحموضة ومؤشر الدهنية في لبن البوذمة من الثلاث أنواع متشابهة (P ≥ 0.05). إحتوت بودرة لبن البقر على رقم بيوروكسيدي أعلى (P ≤ 0.05) من ذلك في بودرة لبن الابل أو الماعز. من بين الثلاث أنواع تحت الدراسة أعطى لبن البقر أعلى (P ≤ 0.05) عائد من لبن البوذمة. لكل الخصائص الحساسة المقاسة ماعدا النزوة، فقد أعطى المحكمين أدنى تقييم للبن البوذمة من الأبل. من حيث العائد والخصائص كان لبن البوذمة الأبقار أفضل من نظيره من لبن بودرة البقر والماعز.
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CHAPTER ONE
INTRODUCTION

Sudan’s milk production for the year 2001 is estimated (FAO, 2002) at just over 7 million tons (MT) of which 37% was available for human consumption, about 60% of production was suckled by the young stock while about 3% went to waste, mainly because of high ambient temperatures and inefficient handling. Elsewhere, individual farmers make their own arrangements for delivery and transport of their milk, (FAO, 2002). Milk defined as the normal secretion of the mammary glands of mammals, milk is the nature designed food for the young and adults. It's a complex mixture that supplies human with carbohydrate (lactose), fat, protein, calcium, essential minerals and vitamins. Milk plays an important role in the dietary intake as it helps to improve bone and dental health and possibly protect against hypertension and colon cancer, for these benefits human being consumes milk from different animal species such as cow, goat and camel. The average composition of liquid milk is 87.3% water, 3.42 – 3.5% protein, 4.78 – 4.90% lactose, 0.75 – 0.7% ash and have a pH 6.6 – 6.8%. To transport milk, farmers use donkeys, donkey – tracted carts and pick – up trucks depending upon availability, cost and the distances involved. Typically, donkeys are used for distances up to 5 – 7 kilometers (kms); donkey, carts for longer distances for 15 to 20 kms, and pick-up trucks for longer distances. There are no refrigerated or cooled transportation facilities which are necessary in a hot climate like that of the Sudan. As a result, after several hours, the milk goes bad. Such problems are compounded by presence of bad roads and the
bacterial growth in raw milk resulting from absence of sanitary methods of milk production and subsequent handling. The most common methods of milk preservation that are used today were heat and low temperature, drying, condensed products, other preservation methods thought off is drying. Dry whole milk powder is an easily reconstituted, economical source of dairy solids, (including milk fat) and a convenient form of nutritious milk. Using dry whole milk powder instead of fluid milk reduces transport and storage costs. Reduced storage space and non refrigerated shipping and warehousing of dry whole milk powder translate into cost savings. Whole milk powders are available in roller-dried and spray-dried form, the latter being more common. In addition, reducing water of milk inhibits microbial growth. The composition of whole milk powder contains 2.0 – 4.5% moisture, 26.0 – 28.5% fat, 24.5 – 27.0% protein, 36.0 – 38.5 % lactose and 5.5 – 6.5% ash. Spray drying is used to dry several liquid foods such as coffee, juice, baby foods and milk. Spray drying is a two stages process. In the first stage the liquid milk is concentrated to 45 – 55 % and in the second stage these concentrated milk is fed into an atomizer for disperse into fine droplets to mix with the hot air in the chamber and quickly evaporate the water from these fine droplets to fine powder and separation of the dry milk. In spite of the great potentialities of sudan in liquid milk production, yet large quantities of dried milk is imported yearly and it is on arise from one year to the other. This is because of the absence of milk powder industry and partially of the scarce research and data about the potentialities of Sudanese liquid milk from different milks animal species. Hence the prime objective of this research is to try to fill the latter gap.
The objectives of this study are:

- To manufacture milk powder from fresh liquid milk obtained from different Sudanese animal species.
- To study the physio-chemical properties of liquid milk and the resulting milk powder.
- To compare the different types of milk powder.
- To determine the yield of milk powder from fresh liquid milk obtained from different animal species.
CHAPTER TWO
LITERATURE REVIEW

2.1 Animal Resources and Milk Production Potentialities in Sudan

Sudan has the second largest livestock population in Africa, next to Ethiopia Table (2.1). However, people in Africa use milk from cows, sheep, goats and camels. Of these sources cow's milk is the most widely produced and processed (FAO, 1990). Ministry of Animal Resources and Fishers (MOARF, 2005) found that the population of cattle, sheep, goats and camels have respectively, increased at the rate 3.1, 3.8, 2.3, and 3.8 % over the last ten years. Cattle are the main source of milk and meat in the Sudan, which produce more than 68% of the total milk production (5,106 out of 7,406 thousand metric tons). Goat population in Sudan was estimated at about 37 million heads, Arab Organization for Agricultural Development (AOAD, 2000). Camel population in Sudan was estimated at 3.724 million heads according to Ministry of Animal Resources and Fisheries (MOARF, 2004).

2.2 Milk

Milk is a complex nutritious product of mammary gland secretion containing water, protein, fat, carbohydrate mainly lactose, mineral and vitamins. Among all foods, milk is the most complete and balanced nutritional contents. Also, milk and its products provide significant amount of protein and micronutrient, including calcium, B-group vitamin (particularly riboflavin, B12 and niacin, B6), vitamin
A, iodine, magnesium, phosphorous, potassium and zinc (Anita, 2001).

2.3 Types of fluid milk:

Bassette and Acosta (1988) reported that the milk products are manufactured from fluid milk by various methods, and they stated that the fluid milks include all of the plain products, with fat contents varying from those from whole to skim milk, as well as flavored and fermented milks. The three main types of milk are whole, partially

2.4 Nutritional Value of milk

Chamberlain (1990) reported that the most important of nutrients in milk to human were proteins, calcium, potassium, phosphorous, other trace elements and vitamins such as A, and B complex. The nutritional value of milk for infants was very clear as it was usually the chief source of complete protein, calcium, vitamins, essential fatty acids and energy for the rapidly developing child (Gamal, 1999). Chamberlain (1990) stated that the whole milk was particularly important for babies less than a year old if breast milk is not available also milk for children is a very important weaning food. O'connor (1995) found that the chief function of lactose in milk was to supply energy for muscular activity and maintenance of body temperature, and lactose also has certain therapeutic properties, it is known to enhance the intestinal absorption of calcium and phosphorus.

Clarence et al, (1982) found that the goat milk generally recognized as an excellent food for a growing child, since milk contains most
Table 2.1: Animal resources estimate during the years 1996 and 2005 (thousand heads).

<table>
<thead>
<tr>
<th>Type</th>
<th>1996</th>
<th>2005</th>
<th>Change % p.a.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>31669</td>
<td>40468</td>
<td>3.1</td>
</tr>
<tr>
<td>Sheep</td>
<td>37202</td>
<td>49797</td>
<td>3.8</td>
</tr>
<tr>
<td>Goats</td>
<td>35215</td>
<td>42526</td>
<td>2.3</td>
</tr>
<tr>
<td>Camels</td>
<td>2915</td>
<td>3908</td>
<td>3.8</td>
</tr>
<tr>
<td>Total</td>
<td>107001</td>
<td>136699</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Source: Ministry of Animal Resources and Fisheries (MOARF) 2005
essential nutrients such as protein, fat and carbohydrate in proportions required by growing children. Therefore, milk is referred to as a perfect food. In addition milk is rich in minerals particularly calcium (Ca) and phosphorus (P) and which were important in developing skeletons of children and this forms about 1.2 g/L of calcium and 1.0 g/L phosphorus and were higher than those in cow milk (Jennes, 1980). Abdel Wahab and Hassan (1968) data on vitamin contents of goat milk showed that goat milk is adequate for the human infant in vitamins A and niacin, and supplies excesses of thiamin, riboflavin, and pantothenate. Thiagarjan (2001) reported that camels milk has a high nutritive value with a high quantity of vitamin C. Bakheit (1999) demonstrated that fat content was 2.8 – 3.6%, protein content was 3.3 - 4.7%, lactose was 4.0 – 5.2%, ash was 0.7 -0.79 % and the total solids were 9.2 – 15 %. Samples of fresh camel's milk from Sudan were found to contain 3.3 -4.7% protein, 2.8 – 3.6% fat, 4.0 – 5.2 % lactose, 0.7% ash and 9.2 – 15.4 % total solids (Dirar, 1993).

2.5 Cow, goat and camel milk Composition

2.5.1 Protein Content

Jenness (1988) stated that the proteins of milk are of great important to human nutrition and influence the behavior and properties of dairy products. Eckles and Macy (2004) found the proteins were among the most complex of organic substances, they contain carbon, hydrogen, oxygen, sulfur and sometimes phosphorous. The average of protein content retried between 2.80 to 4.00 %. Johanson (1980) found the protein content to be 3.50 %. Generally milk protein consists mainly of casein with few other protein fractions
such as lacto–albulin and lacto–globulin. It is an excellent source of proteins that contains all essential amino acid required by humans (Payne, 1990). Philip (1984) reported that fluid milk contains approximately 3.5 % protein, 80 % of it was casein, and the remainders were whey proteins (globulin and albumin). The casein and whey proteins effectively complement each other to give milk its high biological value. The concentration of protein in goat milk was found to range from 2.46 % to 3.70 % (Auqasha and Al-Jiborry, 2002). Also, Jensen (1995) found that the goat milk was slightly similar to camel milk in protein content, which ranged about 2.8 % to 3.9 %. El Hag et al., (2003) and Nabag (2004) determined that the camel milk from Kordofan State and from Butana and found 3.4 % and 3.22% protein respectively. El Badawi (2004) reported that the camel milk in Sudan showed protein content 3.19 %.

2.5.2 Fat content

Ecklas and Macy (2004) reported that the fat was the most valuable constituent of the milk and a great importance from the standpoint of the food value of the milk, they found that the fat content on the average form about 3.8 % fat content which ranged from 3.5 to 5.8% (Jensen, 1995). Khalid and Joseph (1976) reported that fat in the milk of Sudanese cattle was similar to these reported by Khalifa and Bayoumi (1966) which ranged from 3.40 to 5.9 %. On other the hand the fat content of goat milk was found to be in the range of 3.00% to 6.00% Jennes (1980). Mepham (1983) and Jensen (1995) found that the goat milk fat ranged between 3.00 to 3.5 %. Bayoumi (1990) determined the concentration of fat in camel milk and reported 1.9 to 5.6%. Mehaia et al., (1995) studied the chemical
composition of the camel milk and found it to contain 3.22% fat. Dirar (1993) and El Hag et al, (2003), found that the samples of camel’s milk in Sudan ranged from 2.8 to 3.6% and 3.4% fat respectively. The fat content of camel milk in Ethiopia was reported by Knoess (1976) and showed the value of 5.5% fat and agree with Sarwar (2002) in Pakistani camel milk.

2.5.3 Moisture content

Johanson (1980) determined the water content in cow's milk and he reported that 87.20 %. However, Clarence et al, (1951) reported that any variation in the amount of other constituents was also reflected upon the water percentage. On the other hand, the water content of goat milk ranged from 88 % to 90 % (Bencini and Pulina, 1997). Thiagarajan (2001) reported that the camel's milk has a high nutritive value, with a high quantity of vitamin C. According to Mohamed et al, (1989) reported that the water was the main constituent of milk and it forms the major part also, they found that the water content of camel milk ranged from 86 to 91 %. El Hag et al, (2003) found that water content of milk in the camel from Kordufan State, (Sudan) was found to be 89.3 %. El amin and Wilox (1992) stated that the camel milk in Saudi Arabia contained 88.33% water.

2.5.4 Ash content

Milk ash is known to contain potassium, sodium, calcium, magnesium, chlorine, phosphorus and sulfur in relatively large amount, and it was found that the percentage of mineral is about 0.7 % (Ecklas and Macy, 2004). Similar findings were reported earlier by Johanson (1980) and Watt and Merrile (1963).
Sawaya et al., (1984) studied the chemical composition of camel milk and found the ash content to be 0.79%. This finding was confirmed later by Ahmed (1990) who found an ash content of 0.82%. El Hag et al., (2003) in Kordofan State, (Sudan) and Nabag (2004) in Butana area found that the ash content was 0.8% and 0.83% respectively. Ahmed (1989) found that the samples of camel milk in the United Arab Emirates contained 0.65-0.92% ash.

2.6 Physico-chemical properties of Milk

2.6.1 Lactose content

Lactose is a disaccharide consisting of one molecule of glucose linked to one molecule of galactose. It is the only sugar found in milk. Payne (1990) reported that the milk carbohydrates were sugars which were especially important for infant feeding because they prevent intestinal putrefaction by encouraging growth of acid-producing bacteria in the stomach, sugars also affect the absorption of minerals such as calcium and phosphorus. Johanson (1980) found that the lactose content was 4.90%. Philip (1984) reported that milk contains 4.8% lactose (the predominant carbohydrate). Lactose constitutes about 45% solids—not-fat in milk and contributes about 30% of the calories of the whole milk. However, the content of it in goat milk was found to range from 4.1 to 5.2% (Auq and Al-Jibprry, 2002). Iglesias et al., (1984) stated that the lactose content varies between breeds, but they are not of great differences, while Nubian goat’s milk was reported to have 4.67% milk lactose. Similar results were reported by the Black Bedouin goats (Shkolnik and Silanikove, 1981). Goat milk was found to contain about 4% to 4.6% (Jennes, 1980 and Jensen,
Elamin and Wilox (1992) determined the concentration of lactose in camel milk and they reported that the concentration of lactose in camel milk ranged from 2.9 to 5.3 %. In Saudi Arabia, Sawaya (1984) studied the chemical composition of camel milk and reported 4.4 % lactose and this finding agreed with that of Mehaia et al, (1995).

2.6.2 Total solids content (TS)

Khalifa and Bayoumi (1966) reported that the total solids (TS) content of cow’s milk in a dairy herd varied slightly from one season of the year to the other ranging from 13.72 to 14.83%. Idris et al, (1975) reported comparable values of TS to those reported by Khalifa and Bayoumi (1966). On the other hand Khalid and Joseph (1976) reported higher values of total solids (TS) content of cow’s milk varying from 12.13 to 15.39 %.

2.6.3 pH

Murphy (1982) documented that widespread and longtime usage of pH has caused it to consider mathematically equivalent to other biological variables. Mcdowell (1937) showed that in general the pH is lower (down to pH 6.0) in colostrums. However, Prouty (1940) indicated that pH higher (up to 7.5) in cases of mastitis than in normal milk of mid–lactation. Robert et al, (1974) reported that pH of cow’s milk is commonly stated as falling between 6.5 and 6.7 with 6.6 the most usual value. Eckles and Macy (2004) found that pH, or hydrogen-ion concentration of fresh milk was 6.5 to 6.6. Mohamed (2004) Evaluated the quality of milk sold in Khartoum state and found a pH value of 6.50.
2.6.4 Titratable acidity

Gould (1945) declared the possibility that the breakdown of lactose to lactic acid and other acids was responsible for the increase in acidity. Ibrahim (1973) reported that the titratable acidity of Vendor's milk ranges between 0.18 – 0.20 % as lactic acid. International Dairy Federation (IDF) Bulletin (1983) reported that no significant relationship was found between the freezing point and acidity in fresh milk samples where acidity ranged from 0.18 g lactic acid /100 ml.

Sawaya et al, (1984) studied the composition of camel milk and found the acidity content was 0.13% and similar result was reported by Ahmed (1990). Ahmed (1989) found that the samples of camel milk in the United Arab Emirates ranged about 0.11 to 0.14% lactic acid. In Saudi Arabia, camel milk collected from shops was found to contain 0.15% titrable acidity (Abu Lehia, 1987).

2.6.5 Specific gravity

The specific gravity value (15.5°C) for fresh whole mixed herd milk, seldom less outside the range of 1.030 to 1.035 and 1.032 is often quoted as an average value (Robert et al, 1974). The density of milk decreases as the temperature is raised. Siegentholer and Chulthess (1977) highlighted that milk specific gravity is determined by its three major components: water, solid –non –fat and butterfat. Increased butterfat content decreases the specific gravity of milk while increased solids –non –fat increases milk specific gravity. Eckles and Macy (2004) found the specific gravity ranges from 1.027 to 1.035
and is influenced by the relation of its constituents, such as fat, lactose, protein, casein, and salts.

2.6.6. Boiling Point of milk

Milk was slightly heavier than water, and the boiling point of it was (100.17°C) while water boils at (100°C). The variations in the boiling point of milk are of slight little practical importance (Eckles and Macy, 2004). In regions including Africa and South Asian countries, it is common to boil milk after it is harvested. This intense heating greatly changes the flavor of milk, which the respective people are accustomed to (Griffiths and Goffl, 2006). Also, Agoul (1995) reported that Sudanese use boiling as mean of improving milk quality. So boiling is a simple effective preservative method.

2.7. Sensory evaluation

Color

Milk range in color from a bluish- white to a golden – yellow, depending upon the breed of animal. The white color of milk is due to the reflection of light by the dispersed fat globules and the carotene pigment is responsible for the yellow color of milk (Eckles and Macy, 2004).

Flavor

Campbell and Marshel (1975) reported that the off – flavor and odors of milk and milk products can be placed in categories based on their causative factors. The sour flavor (acid) is developed when microorganisms fermented lactose and other carbohydrates. Lactic acid is the primary acid in milk and milk products. However, Eckles
and Macy (2004) found that the odor disappears when milk is allowed
to stand for a few hours or after cooling. Flavor of milk may be
correlated with a high lactose and relatively low chloride content. Off-
flavor may persist, and render the milk undesirable organoleptically,
thereby lowering its commercial value (Old and Sold, 2007). So to
achieve flavor control dairy animals should be clean, healthy, and
properly fed. Also, milking facilities should be clean, dry and well –
ventilated (Campbell and Marshel, 1975).

Taste

Normal freshly drawn milk tastes slightly sweet to most people,
and at the end of the lactating period milk often has such a salty taste
(Eckles and Macy, 2004).

2.8 Treatments and methods of milk preservation

The most common methods of milk preservation that are used
today were described by Fraizeir and Westoff (1981), these include:

i. Use of heat.

ii. Use of low temperature such as refrigerated storage and freezing.

iii. Drying.

iv. Condensed products.

v. Use of irradiation.

vi. Use of chemical preservative.

vii. Developed preservation (fermentation).
Milk powder one of milk preservation methods commonly used in dairy industry.

2.9 Food driers

Christian (1963) stated that drying or dehydration is operatively defined as the process of reversibly removing water from a material so that its shelf life would be extended by the prevention of microbial growth. Such a method has been in practice from the earliest times almost everywhere in the world. Drying foods for preservation is not practically the only reason, since it also helps decrease weight, bulk and consequently reduces the costs of handling, shipping, storage, space and packaging costs as well (Cruess, 1958). Joslyn & Braverman (1954) reported that drying food stuffs is classified as traditional which denotes that drying has been affected by the sun or otherwise artificial i.e. drying by machine to which the term dehydration is strictly confined in which removal of water was carried out under controlled conditions such as temperature, humidity and air speed etc. Duckworth (1966) found that greater control of drying conditions and shorter drying time which were possible with these artificial methods to produce less change in the material and affectively permit acceptable products to be processed from a wide range of raw materials. Each method of commercial food dehydration has specific uses (Hobson, 1983).

2.9.1 Types of Driers

The techniques used for drying food stuff include:
2.9.1.1 Sun Drying Techniques

Traditional method

The sun is environmentally clean, inexhaustible, and consequently sun – drying has been practiced since ancient times. Moreover, sun is the cheapest source of energy and it does not require electricity or investment in equipment or instrumentation and i.e. it is absolutely free. Until relatively recently, Asia, Greece, Spain, and other Mediterranean countries produced most of the world supply of sun drying fruits. Usually fresh fruits after being pretreated are tidily loaded on trays and placed in the sun drying yard for two or three days until they are almost dry (Cruess, 1958). With sun –drying the risk of losses due to disagreeable weather is multiplied (Salunkhe et al, 1976). Drying times depend on various parameters including the amount of sun shine, the humidity of the air, the amount of air movement, dust storms, the amount of moisture in the food (Hobson, 1983).

Utilization of Solar Energy

Bolin and Salunkhe (1982) stated that the solar radiation is unmistakably an efficient source of energy; it is naturally received at the earth's surface and is only limited by means of collecting and utilizing. Increasing product temperature, which in turn causes an increment in vapor pressure, is generally considered the driving force for moisture transfer. This method has been well recognized and extensively applied especially in conjunction with drying of fruits (Donald, 1981).
It has been repeatedly manifested that most solar drying techniques, which use direct solar energy normally, use some means to reflect additional radiation on the product to further elevate its temperature. From one general point of view, the economic feasibility of using solar energy to dry foods is relative. As long as cheap fuel is available for use in this area, solar technique is hard to justify (Singh et al, 1979).

2.9.2 Dehydration Techniques

It is possible to supply heat by infrared, dielectric, and microwave heating methods (Desrosier, 1963).

2.9.2.1 Cabinet Driers

Heid and Joslyn, (1967) stated that heat sensitive products might be dried in temperatures ranging from 80°F to below freezing temperature in vacuum driers, on trays, drawers, or belts. The drier consists of a chamber in which trays of product can be placed. In large driers, the trays are placed on treatment supports in the driers. It was commonly used for laboratory studies and in small scale and reasonable commercial operations (Desrosier, 1963). Cabinet driers are popular since they are relatively cheap to build and maintain, and are indeed very flexible. They are exclusively used singly or in groups and mainly for drying fruits and vegetable (Brennan et al, 1969).

2.9.2.2 Tunnel Driers

Beavens (1944) found that these driers were installed fans by means of which most of the air is re-circulated and the efficiency is greatly increased and common by use for dehydrating fruits and
vegetables. They consist of tunnels 35 to 50 feet long into which trucks containing the trays of food material are placed. Desrosier (1963) stated that air movement may be in the same direction as the movement of food product, or in the opposite direction. In some cases, the two types of tunnels are combined into one unit.

2.9.2.3 Bin Driers

Van Arsel et al, (1973) reported that the bin driers were used particularly in the drying pieces from vegetable products, to complete the drying operation after most of the moisture has already been removed in a tunnel drier, and would be used to reduce the moisture content of a partially dried cut vegetable and he also found that the bin drier consists essentially of a metal or wooden box equipped with air inlet at the bottom and a wire mesh deck on false bottom with an air supply duct below it, arranged so that warm dry air can be passed up through the deck.

2.9.2.4 Kiln Driers

A classic type of dehydration, gives fairly satisfactory results in drying (Beavens, 1944). Desrosier (1963) stated that the Klin driers are commonly two- story buildings. The floor of the upper story is composed of narrow slates, on which food product is spread. Hot gas is produced on the first floor and passes through the product. The material was turned and stirred frequently and a relatively long time was required for drying and it was used for drying of some products such as apple slices, hopes and occasionally for potatoes.
2.9.2.5 Spray Driers

Brennan et al, (1969) reported that this type of driers is used extensively in food industry for drying liquids, slurries, and pastes. The food material is firstly introduced in the form of a fine spray into the chamber, where it was brought into intimate contact with a stream of hot air and they found that the principal components of the spray drying system basically differ in construction, depending upon the product to be dried. The very short drying times, and the relatively low product temperature are the main features of such a system, and if properly operated, a large portion of the flavor, color and nutritive value of the food are retained (Desrosier, 1963). Heid and Joslyn (1967) stated that milk, fruit juice, corn syrup, soluble coffee and other liquid foods are dried by spraying into a chamber using an inject or where heated air is circulated to remove water rapidly from the suspended droplet (Heid and Joslyn, 1967). The main advantage of this process has been collectively observed in the likelihood of heat damage to the material and it was occasional production of too high a proportion of fine powder (Salunkhe, 1976).

2.9.2.6 Vacuum Driers

Brennan et al, (1969) reported that available data illustrate that vacuum dehydration methods are capable of producing dried products of the highest quality, but costs of such a technique are generally higher than other methods. The very low pressure inside the chamber permits the evaporation of moisture and minimized oxidation and they found that the method is especially suitable for drying heat sensitive foods, such as banana and tomato juices.
2.9.2.7 Foam Mat Driers

Van Arsdale (1963) found that this technique has been applied to produce high-quality product from a very wide variety of liquid food concentrates prepared from fruits, vegetables, milk, meat, coffee and from certain starch, or pectin based pudding. In such a method, the material driers rapidly due to the porous nature of the foam, and since evaporation is fast, high heat can be used without impairing flavor and color attributes (Bolin and Salunkhe 1982).

2.9.2.8 Drum Driers

Salunkhe et al, (1974) stated that the drum or roller drier consists of a hollow metal cylinder (2 – 6 ft in diameter), mounted on a horizontal axis which is motorized. Drum driers are particularly designed to handle solutions, fruits, vegetables and sludge materials and it’s processes were used successfully in the production of the powdered cranberries, apple flakes, tomato juice flakes, etc. Brennan et al, (1969) reported that this process has some inherent limitations which restrict the kinds of products. To increase the drying – rate, drum surface temperature must be increased. This ultimately gives the product a more cooked flavor and odor.

2.9.2.9 Freeze-Dryiers

This method involves freezing the material, followed by sublimation under reduced pressure i.e. converting the solid ice from the frozen state to produce a dried product. Sublimation inclusively occurs if the water vapor pressure in the surrounding is below the ice melting pressure, whenever the food is completely dried, it usually has
the same texture and volume as the fresh food but it has been reduced to about 1/3 or 1/5 of its original weight. Gutcho (1977) found that the freeze drying is the best method of producing dried material of high quality and it has a porous texture, and the readily reconstituted to their original size and shape. There is obtained a product of good flavor and appearance and a high retention of nutritive value. In addition, freeze–dried foods are adoptable to simple packing, storage, and shipment. The freeze-drying process is limited by the high cost of the operation and the long drying time.

2.9.2.10 Explosive Puff Drying

Explosive puff drying, which has long been used for preparing rice and wheat breakfast cereals, has been recently expanded to include fruit and vegetable pieces. For a product to be explosive puff dried, it must be partially dried to a moderately low moisture level, and then sealed in a heavy metal cylinder which is pressurized by the application of heat. The pressure is instantly closely released by opening one end of the cylinder. The sudden change in pressure causes the food to expand greatly. This treatment confers to the product a more porous structure, allowing for faster final drying and more rapid rehydration (Salunkhe, 1974).

2.10 Milk powder (Dried milk)

Rosenthal (1991) reported that the milk powder is a product of lower water activity and better keeping qualities and it is produced in large scale in modern plants. The powder produced can be stored for long period of time without significant deterioration of taste or nutritive value and he stated that skim milk can be dried into skim
milk powder to obtain a shelf life of about two years, while whole milk powder can be stored for only six months.

2.11 Types of Milk Powder

2.11.1 Whole Milk Powder

Whole milk powder is a soluble powder made by spray drying of fresh whole milk, and no other drying ingredient comes as close to the composition of fresh milk as whole milk powder (Thompson, 1996). It was usually obtained by removing water from pasteurized, homogenized whole milk (USDEC, 2006). Quality standard for whole milk powder are as follows: fat content 24.0 %, moisture content 4.0%, and solubility index 1.0 (Alfa-Laval Dairy Handbook).

2.11.2 Skim Milk Powder

Thompson (1996) stated that the powder product of milk originally obtained by means of whole milk. It can be found in two forms, regular and instant, but both are made from milk by a spray drying process, both types have the same nutrient composition and he found that the regular type was more compact and requires less storage space than the instant type, but is more difficult to reconstitute. Quality standards for skim milk powder are as follows: fat content 1.5%, moisture content 5.0%, solubility index 2.0. In the production of skim milk powder, the milk is clarified in conjunction with fat separation, and this is also the case if the fat content is standardized in a direct standardization system (Alfa- Laval Dairy Handbook).
2.11.3 Partially Skimmed Milk Powder

It is a powder product of milk originally obtained by means of skimming, concentration and drying of milk (Thompson, 1996).

2.12 Manufacture of Milk Powder

Rosenthal (1991) reported that milk used for making milk powder (whether whole or skim milk), is not pasteurized before use. The milk is pre-heated in tubular heat exchangers before being dried. The pre-heating temperature depends on the season (which affects the stability of the protein in milk) and the characteristics desired for the final powder product. The pre-heated milk is led to an evaporator to increase the concentration of total solids. And he stated that the solids concentration that can be reached depends on the efficiency of the equipment and the amount of heat that can be applied without degrading milk protein.

It is concentrated and then pumped to the atomizer of drying chamber; the milk is dispersed as a fine fog-like mist into rapidly moving hot air system which causes the individual mist droplets to instantly evaporate. Milk powder falls to the bottom of the chamber, from where it is removed (Rosenthal, 1991). Finer milk powder particles are carried out of the chamber along with the hot air system and collected in cyclone separators (Rosenthal, 1991).

Drum-drying and spray-drying are the principal process used to produce milk powder because of their low processing costs (Alfa-Laval Dairy Handbook).
2.12.1 Drum-drying Method

The milk is spread onto rollers which are heated. As the roller revolves, the water evaporates and thin film of milk is left which is scraped off. Milk dried in this way does not reconstitute with water as easily as spray dried milk, and this method is of little use now (Tull, 1996).

2.12.2 Spray-drying Method

Rosenthal (1991) found that the spray-drying is carried out in two stages. In the first stage the pre-treated milk was concentrated by evaporation to dry solids content about 45 to 55%. In second stage the concentrate was fed into a drying tower for final drying and this process takes place in three stages, firstly dispersion of the concentrate into very fine droplets, secondly mixing of the finely dispersed concentrate into a stream of hot air which quickly evaporates the water and thirdly separation of the dry milk particles from the drying air.

He noted that in spray drying the temperature of air entering the drying chamber was approximately 180 to 200 °C and its outlet temperature was 80 to 90 °C. As milk droplets lose water, the latent heat of evaporation continuously loses their surface, so that temperature of the milk never exceeds 75 °C.

Evaporation is a necessary production stage of high quality powder (Alf – Laval Dairy Hand book). Ozmen and Languish (2003) stated that spray dryers have to be cleaned frequently due to the deposition of the powders on the walls. They also added that the
buildup of the powder deposits in a spray drier is undesirable because they undergo oxidation and browning or scorching and will degrade the quality of the final product if they fall off and mix with it.

2.13 Physical Properties of Milk Powder

Many physical powder properties can be influenced by certain pretreatment process, by choosing the conditions for the evaporation and spray drying and by applying various post-drying treatments.

2.13.1 Moisture content

The moisture content of a powder is often subject to (legal) product specifications defining the maximum moisture content. This based on the fact that too high moisture content may result in inferior shelf-life, creation of lumps and possibly microbiological problems (Van Mil and Jans, 1991).

2.13.2 Insolubility Index

When milk powders are reconstituted and centrifuged, some insoluble fractions can be observed, this is considered as a quality defect. Several methods have been developed to determine the insolubility of milk powders. The most well defined method is the International Dairy Federation's method for the determination of the "insolubility" (IDF, 1988).

2.13.3 Bulk density

Bulk density expresses the weight of powder per unit volume and is expressed in Kg /m³. Bulk volume is also often used in the milk powder industry and is expressed as a volume in ml of 100g of
powder. Bulk density of dairy-based powder is a very important property from the point of view of economy, functionality and market requirements (Walstra et al, 2005).

2.13.4 Flowability

Good flowability is especially important when the powder will be processed or used without mechanical handling and dosing devices. Examples of applications that require good flowability are powder to be used on coffee vending machines and milk replacer used by farmers for feeding calves (Walstra et al, 2005).

2.13.5 Free Fat

Traditionally, the term "free fat" has unfavorable associations in terms of shelf-life (oxidation), instant properties and deterioration of flow ability.

Buma (1971) developed a physical model, dividing the extractable fat in four forms, which made the term "free-fat" more comprehensible:

1- Surface fat 2- Outer layer fat
3- Capillary fat  4- Dissolution

2.13.6 Instant Properties

Instant properties also called reconstitution properties involve the ability of the powder to dissolve quickly and completely in water. This ability features a rather complicated mechanism. Each individual particle has initially to be wetted, then to sink into the liquid in order to be finally dissolved. The most important instant properties are
wettability and dispersibility (IDF, 1979), that are define susceptibility to the water penetration (wettability) and powder ability to disperse and mix in water, forming a homogeneous liquid (dispersibility).

2.14 Chemical Composition of Milk Powder

According to a ruling set forth by the U.S. Department of Agriculture, dried milk made from whole milk must contain not less than 26 percent of milk fat, and the moisture content must not exceed 5 percent.

The dry milk manufacture, therefore, takes every precaution to ensure a product which will conform to the United States standards. The composition of dry milk varies according to the composition of the milk from which it is made. Due to elimination of most of water in the process of drying, the other milk constituents are increased in about the same production (Eckles and Macy, 2004).

2.15 Defects of Milk Powder

Thomas et al, (2004) reported that the milk powder was now considered as a food ingredient mainly because of the functional properties of milk protein. During storage of milk powder, physiochemical damages, mainly dependent on lactose glass transition. Thomas et al, (2004) found that the main physiochemical and biochemical damages occurring upon storage are lactose crystallization, sticking and caking problems, and biochemical reactions especially Maillard reaction.
Table 2.2: The chemical composition of milk powder.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Whole milk</th>
<th>Cream milk</th>
<th>Skim milk</th>
<th>Sourbutter milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (%)</td>
<td>4.00</td>
<td>0.66</td>
<td>4.00</td>
<td>1.93</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>27.20</td>
<td>13.42</td>
<td>37.40</td>
<td>38.74</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>26.00</td>
<td>65.15</td>
<td>1.00</td>
<td>5.87</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>36.80</td>
<td>17.86</td>
<td>49.20</td>
<td>39.91</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>6.00</td>
<td>2.91</td>
<td>8.40</td>
<td>7.68</td>
</tr>
<tr>
<td>Total solids (%)</td>
<td>96.00</td>
<td>99.34</td>
<td>96.00</td>
<td>98.07</td>
</tr>
</tbody>
</table>

2.15.1 Lactose crystallization

Thomas et al, (2004) stated that lactose is the most abundant component in fresh whole milk (4.9%) and in freshly spray dried milk powder, lactose is amorphous. During storage, an increase in temperature or relative humidity enhances lactose crystallization which is one of the main phenomena responsible for the modification of the surface chemical composition of milk powder particles and they stated that during the storage of milk powder, lactose crystallization enhances the migration of internal fat onto the particle surface, and generates a network of capillary in the whole particle. Thomas et al, (2004) reported that the oil droplets are stressed inside the particles and forced to spread onto the particle surface. Lactose crystallization is correlated with a decrease of milk powder’s flowability, and involves modification of protein structures and damages the solubility of milk powders.

2.15.2 Sticking and Caking

Foster et al, (2005) stated that high fat powders, such as cream powder and cheese powder have been known to experience sticking and caking problems during processing and storage. During processing, high fat powders cause smearing, where the powder builds up on the inside of the driers, cyclones and fluidized beds. During storage, lumps of powder, are formed which are difficult to break up form. Milk fat has been stated as the cause of caking in a number of studies. Viscous liquid bridges may cause flow difficulties in fat-containing powders. If the temperature is increased during storage, some fat may melt forming liquid bridges of fatty composition.
Thomas *et al*, (2004) stated that a powder collapse occurs when it was not rigid enough to support its own weight. Collapse is the shrinkage of powder particles, and it induces important structural changes in powders. Particle volume decreases since particles are crushed, thus collapse is linked to a decrease in porosity and an increase in density. Also they noted that particle agglomeration is a problem, since caked milk powders are seen as low quality products by consumers and impair flowability. They stated that collapse, caking and sticking are inter-linked and occur simultaneously during the storage of milk powder and it is difficult to study each phenomenon separately, that the initial stage agglomeration corresponds to the collapse, particle shrink and the number of inter-particle content increases and the particles then start to adhere (sticking), before being strongly stuck (caking).

Both fat and lactose have strong influence on the stickiness of milk particles. The stickiness of these particles is particularly sensitive to small changes in the fat content between 0 – 5%, which is due to a rapid change in surface fat coverage from 0 – 35% (Nijdam and Longrish, 2006).

### 2.15.3 Maillard reaction

Thomas *et al*, (2004) stated that Maillard reaction is a biochemical reaction between protein and reducing sugars in food. In milk products, it begins by lactose condensation on same amino acid residues (lactosylation) and involves a wide range of chemical reactions.

This reaction is mainly induced by heat treatment and generally damages milk powder quality and they found that the nutritional
quality is also worsened, because essential amino acid residues of milk protein are less available when linked to lactose and because the digestibility of milk proteins lessened and this reaction implies food safety problems (Thomas et al, 2004).

2.15.4 Peroxide Value (PV)

Hartley (1967) found that the oxidation of lipids to hydroperoxides, referred to as the peroxide value (PV) of a fat represents the reactive oxygen content and is estimated through the liberation of iodine from potassium iodide. Thomas et al, (2004) stated that oxidation increases with storage time, and thus damages the quality of milk powders. And they added that oxidation occurs even at very low water activities, since the migration of hydrophobic compounds (fats) does not depend on water mobility. In the primary stage of milk powder, oxidation was dominant during the first six months of storage period and that in the secondary stage, oxidation dominated during the subsequent six months of storage period (Farkye et al, 2001). Oxidation limits the product's shelf life and adversely affects quality and consumer acceptability (Farkye et al, 2001).

2.15.5 Lipolysis and proteolysis

Chen et al, (2003) studied lipase activity and the free fatty acid content in whole milk powders. Lipase activity was found to be stable throughout eight months of storage. Free fatty acids were constantly liberated from triglycerides by lipases and accumulated during powder storage. Although lipases were active even at 3°C, larger values of free fatty acids were obtained at higher storage temperature of 25°C. They
also reported that this is detrimental to milk powder quality, since free fatty acids readily oxidize and bring off-flavors. 

Chen et al, (2003) stated that proteolysis in milk powder has been measured by monitoring changes in nitrogen levels such as the decrease in casein nitrogen or increase in non-protein nitrogen (NPN). These changes have been linked to changes in functionality, such as microstructure changes (e.g. casein flocculation) and increase in viscosity in ultra high temperature (UHT) milk. Thomas et al, (2004) stated that the storage of whole milk powders did not significantly affect the proteolytic activity.

2.16 Storage of milk powder

The critical factor in the storage of dairy products is temperature. The recommended temperature varies according to the nature of the product, but any rise, and for some products any drop in temperature, could be detrimental. A reliable temperature control and monitoring system will prevent any temperature problems (Alfa-Laval Dairy Handbook).

Beside temperature, the length of time for which the product is stored from the date of production to the date of consumption must also be monitored, and every dairy product has a definite shelf life at recommended storage conditions (Alfa-Laval Dairy Handbook).

Farkye and Obispa (1998) stated that moisture content and water activity of foods are the critical parameters that influence shelf life in milk powder. Excessive moisture causes caking, promotes spoilage loss of quality and water activity of milk powder influences on enzymatic and oxidative changes that occur during storage and growth of micro-organisms.
CHAPTER THREE
MATERIALS AND METHODS.

3.1 Materials

3.1.1 Liquid milk samples

The liquid milk samples such as cow, goat and camel, were collected in the morning from different farms in Khartoum state,

Cow and goat milk from faculty of Agriculture farm in Jun and July months respectively, and camel milk was collected from Al-Ass farm (Shambat) in May month. The amount of each sample was 11 lb, and packaged into stainless steel container.

3.2. Methods

3.2.1 Milk powder manufacture

Spray Drying Method

1st step: Accurately weighed 10 lb of liquid milk samples (cow, goat, camel) were concentrated by using rotary evaporator, and continues evaporated about 2 – 3 hr until the total solids reached 30 – 50 %. This step is important to avoid over – heating.

2nd step: The concentrated milk samples were transferred to spray drier model Anhydro, Type lab S1, the drying conditions were 180°C, a flow rate of 20 ml/min and a pressure of 1.5 bars.

Immediately the dried milk samples were transferred from spray dryer, cooled, weighed and packaged in stain less steel containers. The yield was calculated as flows:-
Yield (%) = \frac{\text{Weight of milk powder}}{\text{Weight of liquid milk}} \times 100

3.3 Samples Analysis

The samples of liquid milk were analyzed for chemical and physical properties such as fat, protein, moisture, ash, lactose, pH, titrable acidity, total solids and total soluble solids. Additionally whole milk powder was analyzed for peroxide value and solubility.

3.4 Proximate Analysis of liquid and powder milk

These dried products were hygroscopic in nature. Care must be taken while handling these samples to avoid moisture absorption, which can give erroneous results.

3.4.1 Protein determination

Protein content was determined by Kjeldahl method according to the AOAC (2003) as follows:

- Digestion: Ten grams of each sample were weighed in a crucible and transferred to a digestion flask. Two tablets of Kjeldahl catalyst (mercury) and 3 ml of concentrated sulphuric acid (sp.g.1.84) were added to the sample. The flask was placed on the digestion apparatus, heated strongly until the liquid had become clear.

- Distillation: The digested sample of milk and fifteen ml of NaOH (40%) were added to kjeldahl distillation apparatus. Ten ml of boric acid (2%) and three drops of indicator (methyl red) were added to a receiving flask. The distillation was continued until the distillate in the receiving flask was 75 ml.
-Titration: The sample in the receiving flask was titrated against HCL (0.1N) until the color was changed to a faint pink. The protein content was calculated as flows:

\[
N \% = \frac{T \times 0.1 \times 20 \times 0.014 \times 100}{\text{Weight of sample}}
\]

Where:

- \(T\) = Titration figure
- \(20\) = dilution factor
- \(0.014\) = atomic weight of N/1000

Protein \((\%) = N \ (%) \times 6.38\)

Where:

- \(N\) = nitrogen content
- \(6.38\) = conversion factor

3.4.2 Fat determination

The fat content was determined by Gerber method according to AOAC (2003). Ten ml sulphuric acid (density 1.815 gm/ml at 20 °C) were poured into clean dry Gerber tubes (for milk powder cold water was added so that a layer was formed on top of the acid about six mm deep), then 10.96 ml (10.97g) milk were added followed by the addition of 1 ml amylalcohol (sufficient hot distilled water was added for milk powder about 70 °C, and liquid milk about 20°C). The
contents were mixed well (and for milk powder placed in a water path at 65 °C for 3 – 10 minutes) and centrifuged at 1100 rotations per minute (r. p. m) for five minutes.

3.4.3 Moisture determination

The moisture of milk sample was determined according to Pearson (1976). Five grams of milk sample were placed into aluminum dish and dried in the oven 105 °C for two hours with the lid along side. The lid was placed on the dish and transferred to the discator, the sample was weighted when the dish had completely cooled. The moisture percent of the sample was calculated as follow:

\[ \text{Moisture} \% = \frac{(B - C)}{A} \times 100 \]

Where:

\[ A = \text{sample weight in grams} \]
\[ B = \text{weight of dish + sample prior to drying} \]
\[ C = \text{weight of dish + sample after drying} \]

3.4.4 Ash determination

The ash was determined according to Pearson (1976). A porcelain dish dried in an oven, cooled into the discator and then weighed. Three grams of milk sample were placed into the dish and burned in furnace 660 °C until free from carbon (residue appears grayish - white) about two hours, it was transferred to the discator to cool – down. The dish and sample was then re – weighed when the dish had completely cooled. The ash percent of the sample was calculated as follow:
Ash % = \frac{B - C}{A} \times 100

Where:

A = sample weight in grams
B = weight of dish and contents after drying
C = weight of empty dish

3.4.5 Lactose determination

Was determined by Lane and Eynon method according to AOAC (2003). 25 ml from liquid milk and 25 g from whole milk powder were dissolved in distilled water, clarified by lead acetate (2 ml), and potassium oxalate (3 ml), then filtrated and made up to (250 ml). 10 or 25 ml of mixed fehling solution was prepared in 300 ml conical flask. 15 ml of sugar solution was added and liquid was boiled on asbestos covered gauze 1 ml of sugar solution was added at (10 – 15 sec) boiled liquid until the color was nearly discharge 3.5 drops of methylene blue indicator added to the boiled liquid. The boiling was continued until the indicator color was completely decolorized. The lactose content was calculated from the lactose table.

3.4.6 Total solids determination

The total solids were determined according to AOAC (2003). Five grams of milk (2 g from milk powder) were placed into a clean dried aluminum dish. The weight of the sample and dish were recorded. The dishes were heated on a steam bath for 10 – 15 minutes this stage for milk powder and earthier samples (liquid & powder)
were transferred to an air oven for 12 hours at 75 °C. The dishes were placed into a discator to cool and then weighted. Heating, cooling and weighting were replaced several times until difference between two successive weightings was less than 0.5 mg.

The total solid content was calculated as follows:

\[
\text{Total solid (\%) } = \frac{W_1}{W_0} \times 100
\]

Where:

\[ W_1 = \text{weight of sample after drying} \]
\[ W_0 = \text{weight of sample before drying} \]

3.4.7 pH and titratable acidity measurement

The pH of the milk was determined according to Foley et al (1974). (Model Hanna / instrument Bench meter, HI 255). The acidity of the milk samples was determined according to Pearson (1976). Milk sample (10 ml) was measured into a glass beaker and three drops of phenolphthalein indicator (colourless) were added. This was titrated against 0.1N sodium-hydroxide until a faint pink color (end point). The titration figure was divided by 10 to give the acidity of the sample expressed as percentage lactic acid. (Milk powder was determined as liquid milk after stirring 1g of samples were added to the 10 ml hot water about 80 °C). The acidity was calculated from the following equation:

\[
\text{Acidity} = \frac{X \times 0.09 \times 0.1}{\text{Weight of sample}} \times 100
\]

Where:

\[ X = \text{titration figure} \]
0.09 = molecular weight of lactic acid

0.1 = N sodium hydroxide

3.4.8 Specific gravity

The specific gravity of milk was determined as described by Pearson (1976). The specific gravity of milk was measured by a lactometer; a certain amount of milk was poured into a measuring cylinder. The milk temperature was read using a thermometer and the temperature was recorded. The lactometer was then immersed in cylinder and the reading was taken. The specific gravity of milk was then computed from the following:

\[
\text{SP.G} = 1 \pm \frac{C. \ L. \ R}{1000}
\]

Where:

- \( \text{SP.G} \) = specific gravity
- \( C. \ L. \ R. \) = Correct Lactometer Reading

3.4.9 Solubility

The solubility was determined according to Pearson (1976). Five grams of milk powder were mixed with 32 ml hot distilled water about (50 °C) for 10 sec and placed in water bath (50 °C) for 5 min then centrifuged the hot reconstituted milk in a 25 ml tube for 10 min at 2000 rpm. Cooled in refrigerator and removed the fat layer after running a needle around the cake of fat. Warmed to 20 °C, broke up the deposited with a rod and shaken the corked tube hard to produce apparent homogeneity and weighed about 2 ml (weight \( L_1 \)) of liquid...
into a weighed metal dish with lid. Also, centrifuged the reconstituted milk for 10 min and weighed about 2 ml (weight L₂) into another dish. Dried both dishes on a water bath and then in a 100 °C oven for 1½ hr, cooled and weighed if the weight of the dried solids corresponding to L₁ and L₂ were S₁ and S₂ respectively.

The solubility of milk powder was then calculated from the following:

\[
\text{Solubility (\%) = } \frac{100 \times (L_1 \times S_2)}{L_2 \times S_1}
\]

**3.4.10 Peroxide Value (PV)**

Peroxide value (PV) of milk powder which indicates the extent of overall oxidation was determined according to the AOAC (2003). Ten grams of milk powder were weighted in conical flask (250 ml), 50 ml of solvent hexane were added closed tightly, left overnight, filtered by filter paper and the filtrate was placed at atmospheric to evaporate the solvent. After that one gram of the milk powder sample was accurately weighed into 250 ml conical flask. Thirty ml of a mixture of acetic acid and chloroform (3:2) were added and the mixture was swirled gently to dissolve the milk powder. Then 0.5 ml of 0.1 N KI was added. The contents of the flask were left to stand for one minute and 30 ml of the distilled water were added. After a while the contents were titrated with 0.01 N sodium thiosulphate until the yellow color almost disappeared. 5 ml of 1% starch solution was added. Then titration was continued with vigorous shaking until the blue color disappeared. The numbers of mls of 0.01 N sodium thiosulphate required were recorded.
The same operation was carried out under the same conditions, but without the oil tested (blank). Later the number of mls of 0.01 N Sodium thiosulphate required was recorded.

The peroxide value of milk powder was then calculated from the following:

\[ \text{Peroxide value (PV)} = \frac{(b - a) \times N \times 100}{S} \]

Where:

- \( a \) = Reading of milk powder sample (ml).
- \( b \) = Reading of blank (ml).
- \( s \) = Original weight of milk powder sample (g).
- \( n \) = Normality of Sodium thiosulphate.

### 3.5 Sensory evaluation of liquid and dried milk

Milk samples were subjected to sensory evaluation for color, flavor, taste, viscosity and overall acceptability using ten untrained panelists from the faculty of Agriculture university of Khartoum.

### 3.6 Statistical analysis

The data collected were subjected to analysis of variance and whenever appropriate the mean separation producer of LSD was employed (Steel and Torrie, 1980). The SAS program (SAS institute, 1988) was used to program the GLM analysis.
CHAPTER FOUR
RESULTS AND DISCUSSION

This study was carried out to determine and compare the physical and chemical composition of goat, cow and camel liquid milk and powder milk. Various parameters including pH, acidity, lactose, specific gravity, total solid, protein, fat, moisture, ash, peroxide value and solubility index for milk powder to these milk types were analyzed.

4.1 Chemical Composition of liquid milk

4.1.1 Protein Content

With regard to the data shown in Table (4.1), the protein content of goat, cow and camel liquid milk were found to be 4.54%, 3.93% and 4.20% respectively. Goat had significantly ($P \leq 0.05$) the highest protein content and cow milk had the lowest. Our results in cow milk and goat are higher than that obtained by Aqush and AL- Jiborry (2002) in goat milk and Eckles and Macy (2004) in cow milk, they reported 3.08% and 3.4% respectively. However, protein content in camel milk was higher than that reported by Nabag (2004) who reported 3.22% and lower than that obtained by EL-Badawi (2004) and EL-Hag et al (2003), who reported 11% and 3.4% respectively.

4.1.2 Fat Content

The results of the fat content of these types of liquid milk are presented in Table (4.1). The mean values of fat content of goat, cow and camel milk were 3.13%, 5.17% and 3.10% respectively. The cow
Table 4.1: The proximate composition of liquid milk from different animal species

<table>
<thead>
<tr>
<th>Species</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Moisture (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat</td>
<td>4.54 (^a) ± 0.04</td>
<td>3.13 (^b) ± 0.06</td>
<td>87.87 (^b) ± 0.07</td>
<td>0.81 (^a) ± 0.006</td>
</tr>
<tr>
<td>Cow</td>
<td>3.93 (^c) ± 0.05</td>
<td>5.17 (^a) ± 0.15</td>
<td>84.94 (^c) ± 0.04</td>
<td>0.83 (^a) ± 0.04</td>
</tr>
<tr>
<td>Camel</td>
<td>4.20 (^b) ± 0.02</td>
<td>3.10 (^b) ± 0.10</td>
<td>88.90 (^a) ± 0.03</td>
<td>0.71 (^b) ± 0.006</td>
</tr>
</tbody>
</table>

\(n = 3\)

\(a – c = \) means in the same column bearing similar superscript letters are not significantly different (\(P \geq 0.05\))
liquid milk showed higher fat content than goat and camel milk. Apparently goat and camel liquid milk had similar \((P \geq 0.05)\) fat content. The current results fat content in cow milk was higher than that obtained by Eckles and Macy (2004). On the other hand, fat content of goat and camel milk reported in this study were almost in full agreement with those reported by Mepham, (1995) and Mehaia et al, (1995). Fat contents of milk from different species reported in this study were slightly lower for goat and camel but significantly higher for cow than that reported by Eckles and Macy (2004). Difference between the two studies could be attributed to breed differences or seasonal, nutritional, lactation period, or other physiological variation.

4.1.3 Moisture Content

According to the results summarized in Table (4.1). Goat liquid milk 87.87% was significantly \((P \leq 0.05)\) higher than that of liquid cow milk 84.94%, but slightly \((P \leq 0.05)\) lower than that of camel milk. While the fluid cow milk was different significant \((P \leq 0.05)\) than that of fresh liquid camel milk 88.90%. Our moisture content for camel milk was higher than the findings of EL-amin and Wilox (1992), however slightly lower than that of EL- Hag et al (2003). Johanson (1980) and Bencini and Pulina (1997) found a moisture content of 87.2% and 89% for cow and goat milk respectively.

4.1.4 Ash Content

The ash content of milk from different animal species is shown in Table (4.1). Milk from the three species had comparable content particularly goat and cow \((P \geq 0.05)\). Obviously camel milk had significantly \((P \leq 0.05)\), the lowest ash content among the milk from
the two species under investigation. The result of the ash content of cow milk was slightly higher than that obtained by Eckles and Macy (2004) who found it to be 0.7%. However, camel milk in ash content was slightly lowest than those reported by Nabag (2004) who found it to be 0.83%.

4.2. Phyisco – chemical properties of liquid milk

4.2.1 Lactose content

Goat milk had the highest lactose content among the milks of the three species under investigation. Statistically goat and camel milk had similar (P ≥ 0.05) lactose contents table (4.2). On other hand cow and camel milk had similar (P ≥ 0.05) lactose contents; however goat milk had higher (P ≤ 0.05) lactose than cow milk. Auq and AL-jiborry (2002) and Iglesia et al., (1994) reported higher lactose content in goat and camel milk i.e. 4.65% and 4.67% respectively. Our finding in this study, were comparable to that of EL-Hag et al., (2003) and Knoess (1976) who cited 3.6% and 3.4% for the milk from the above tow species respectively. Lactose content in camel and cow milk were lower than those reported by Mehaia et al, (1995) and Phlip (1984) who recorded 4.4% and 4.8% respectively.

4.2.2 Total solids Content

According to the results summarized in Table (4.2) apparently the total solid (TS) content was reported for cow milk 13.31 and the lowest for camel milk 11.47. The mean T.S of cow, goat and camel milk was significantly different (P ≤ 0.05). Singh et al, (1979) stated that milk composition is affected by several factors like environmental, physiological once within the same species. The breed
Table 4.2: Physico-chemical properties of liquid milk from goat, cow and camel.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Goat</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>3.56(^a) ± 0.04</td>
</tr>
<tr>
<td>Total solid (%)</td>
<td>12.18(^b) ±0.06</td>
</tr>
<tr>
<td>pH</td>
<td>6.80(^a) ± 0.10</td>
</tr>
<tr>
<td>Titrable acidity (%)</td>
<td>0.18(^b) ± 0.006</td>
</tr>
<tr>
<td>S. Gravity</td>
<td>1.029(^a) ± 0.04</td>
</tr>
</tbody>
</table>

n = 3

\(^a\) – \(^c\) = means in the same column bearing similar superscript letters are not significantly different (P ≥ 0.05)
can have a clear effect on the milk composition (Alssandro et al.; Sollberger and Schaeren, 2003). Alssandro et al., (1995) claimed that the Anglonubian goat produced milk with more total solid and solids non fat than Sannen goats. Similar findings were reported later by Sollberger and Schaeren, (2003) working on Brienz and Saanen goat breed.

### 4.2.3 pH

The physico-chemical properties of fresh liquid milk from different animal species are shown in table (4.2).

From table (4.2) it can be seen that the mean pH value of goat and cow liquid milk 6.80% and 6.80% respectively were significantly different ($P \leq 0.05$) from that of camel fresh milk 6.25%. pH for goat and cow milk were higher than those findings of Robert (1974) and Eckles and Macy (2004). Also camel milk had lower pH value than that reported by Mohamed (2004).

### 4.2.4 Titratable acidity

The acidity of liquid milk from these different species is reported on Table (4.2). The mean value of acidity content in liquid goat and cow milk 0.18% and 0.18% respectively were not significantly different ($P \geq 0.05$) from camel milk 0.24% which is higher ($P \leq 0.05$) than both of them. The value reported of cow milk in this study is slightly less than those reported by Ibrahim (1973) and Bulletin (1983). They cited 0.19% and 0.18% respectively. However, the acidity content in camel milk was slightly higher than those obtained by Abu-Lehia (1987) who recorded 0.15%. 

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4.2.5 Specific gravity

The specific gravity of goat, cow and camel fresh milk is presented in Table (4.2). The results indicate significant differences (P ≤ 0.05) in the specific gravity of the milk from the three species goat 1.029, cow 1.025 and camel 1.027. The lowest value was reported for that of cow and the highest for that of goat. The finding of the current study for the specific gravity of goat milk was in full agreement with that reported by Hassan, (2005)

4.3 Chemical Composition of milk powder

4.3.1 Protein Content

The result of protein content of goat, cow and camel milk powder are presented in Table (4.3). Protein goat milk powder 24.84 % was significantly higher (P ≤ 0.05) than that of dried camel milk 20.85%, while that of cow milk powder 22.44% was significantly lower (P ≤ 0.05) than that of goat milk powder. In results of protein content were lower than those observed by Eckles and Macy (2004) who reported 27.20%.

4.3.2 Fat Content

According to the results summarized in Table (3), goat milk powder 33.28 had significantly higher fat (P ≤ 0.05) value than that of dried cow milk 31.57% or camel milk powder 29.28%. The fat values reported in this study were slightly higher value than that reported by Walstra et al, (2005) who cited 27.25% or as reported by Web et al, (1974) who reported 27.5%. 
Table 4.3: The proximate composition of milk powder made from goat, cow and camel milk (%)

<table>
<thead>
<tr>
<th>Species</th>
<th>Protein</th>
<th>Fat</th>
<th>Moisture</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat</td>
<td>24.84 (a \pm 1.03)</td>
<td>33.28 (a \pm 0.05)</td>
<td>5.25 (a \pm 0.04)</td>
<td>6.59 (a \pm 0.04)</td>
</tr>
<tr>
<td>Cow</td>
<td>22.44 (b \pm 1.03)</td>
<td>31.57 (b \pm 0.04)</td>
<td>4.78 (b \pm 0.02)</td>
<td>5.72 (b \pm 0.02)</td>
</tr>
<tr>
<td>Camel</td>
<td>20.85 (c \pm 0.03)</td>
<td>29.28 (c \pm 0.03)</td>
<td>5.39 (a \pm 0.05)</td>
<td>6.58 (a \pm 0.04)</td>
</tr>
</tbody>
</table>

\(n=3\)

\(a – c = \) means in the same column bearing similar superscript letters are not significantly different \((P \geq 0.05)\)
4.3.3 Moisture Content

The moisture content of milk powder from the different species under investigation is displayed on Table (3). The mean values of moisture content in goat 5.25% and camel 5.39% milk powder were not significantly different ($P \geq 0.05$), while cow milk powder 4.78% was significantly different ($P \leq 0.05$) from that of goat and camel milk powders. The moisture content reported in this study for the milk powder produced from the milk of the different animal species is at least twice higher than that reported by Web et al, (1974).

4.3.4 Ash content

As shown in Table (4.3), the ash values of goat 6.59%, cow 5.72% and camel 6.58% milk powder. The goat and camel milk powder had similar ($p \geq 0.05$) ash content. However, cow milk powder ash content was significantly ($p \leq 0.05$) lower than that of camel and goat milk powder. Goat and camel milk powder ash content results were in agreement with Walstra et al, (2005) who reported a value of 6.3%. On the other hand, the cow milk powder ash content was similar to that reported by Web et al, (1974).

4.4. Physico-chemical properties of milk powder

4.4.1 Lactose Content

The lactose content of goat, cow and camel milk powder is presented on Table (4.4). The lactose contents of cow and camel milk powders were similar ($P \geq 0.05$). The values reported in this study were less than that reported by Eckles and Macy (2004) who gave a
value of 36.80 % and that of Web et al, (1974) who gave a value of 38.2%.

4.4.2 Total solids content

As illustrated in Table (4.4) it is clear that TS content of goat and cow milk powders were not significantly different (P ≥ 0.05). However, they were significantly higher (P ≤ 0.05) than that of camel milk powder. TS content of goat 93.98%, cow 93.86% and camel 90.26% were lower than that specified (95%) by Sudanese standards SSMO (2002). TS content of cow and goat milk powders reported in this study are similar to that reported by Mohamed (2006). However camel milk powder TS content in our study is considerably less than that in Mohamed (2006) study. Species difference feed or season in the two studies could be the reason.

4.4.3 pH

The physical properties of milk powder made from different types of animal are shown in Table (4.4). From Table (4.4) the mean value of goat, cow and camel milk powder were 6.30%, 6.00% and 6.37% pH respectively. The pH of dried camel milk shown significant difference (P ≤ 0.05) in value than that of goat and cow milk powder, while the mean value of dried goat milk showed insignificantly difference (P ≥ 0.05) from that of the cow and camel milk powder.

4.4.4 Titratable acidity

According to the result summarized in Table (4.4), the goat, cow and camel milk powder had almost similar (P ≥ 0.05) titrable acidity.
Table 4.4: Physico chemical properties of milk powder made from goat, cow and camel milk.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Goat</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>28.97(^b) ± 0.02</td>
</tr>
<tr>
<td>Total solids (%)</td>
<td>93.68(^a) ± 1.56</td>
</tr>
<tr>
<td>pH</td>
<td>6.30(^{ab}) ± 0.03</td>
</tr>
<tr>
<td>Titrable acidity (%)</td>
<td>0.16(^a) ± 0.03</td>
</tr>
<tr>
<td>Solubility (%)</td>
<td>90.18(^a) ± 0.03</td>
</tr>
<tr>
<td>PV (meq/kg fat)</td>
<td>4.89(^c) ± 0.01</td>
</tr>
</tbody>
</table>

\(n = 3\)

\(a – c = \) means in the same raw bearing similar superscript letters are not significantly different \((P \geq 0.05)\)
Dried camel milk showed the highest acidity index 0.17% followed by goat milk powder 0.16% and the least acidity was recorded in dried cow milk 0.15%. The value of acidity of dried milk was found to be higher than that reported by Mohamed (2006) who gave value (0.015) which is in agreement with cow milk powder.

4.4.5 Solubility index

According to the result summarized in Table (4), the goat, cow and camel milk powder had similar (P ≥ 0.05) solubility index. Numerically dried cow milk showed the highest solubility index 92.15% followed by camel milk powder 91.98% and the least solubility index was recorded in dried goat milk 90.18%.

4.4.6 Peroxide Value (PV)

With regard to the data shown in Table (4.4), the peroxide value of goat 4.89%, cow 5.80% and camel 9.85% for milk powder. The mean values of dried milk samples showed significant difference (P ≤ 0.05).

4.5 Milk powder yield

As illustrated in Table (4.5) it is clear that the yield of dried goat, cow and camel milk in the present study are 13.17%, 16.44% and 11.99% respectively. The higher value in this study was found in cow milk powder and the lowest recorded in the dried camel milk. The mean values of dried samples showed significant difference (P ≤ 0.05).
4.6 Sensory characteristic of liquid milk from different animal species

The score of color of three liquid milk samples is presented in table (4.6). The color score ranged between 4.3 and 4.5. The highest value (4.5) was showed by fresh goat and cow milk while the lowest value (4.3) was showed by liquid camel milk. Cow and goat liquid milk had similar (P ≥ 0.05) color where as camel milk had significantly (P≤ 0.05) lower color score than that of cow or goat milk. The score of flavor preference ranged from 2.4 to 4.5. The most preferred flavor score (4.3) was for cow milk while the least preference (2.4) was for fresh goat milk. The flavor of cow milk was significantly (P ≤ 0.05) preferred by the panelists over that of camel or goat milk. The score of taste preference ranged between 3.6 and 4.3. The most preferred (P ≤ 0.05) taste was for cow milk, while the least preferred milk taste was for camel and goat liquid milks. The panelist preferred significantly (P ≤ 0.05) the taste of cow milk over that of goat and camel milk, while they rated goat and camel milk taste equal
Table 4.5: The yield of milk powder made from different animal species

<table>
<thead>
<tr>
<th>Species</th>
<th>Liquid milk</th>
<th>Powder milk</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount (L)</td>
<td>Yield (kg)</td>
<td></td>
</tr>
<tr>
<td>Goat</td>
<td>10</td>
<td>1.317</td>
<td>13.17b ± 5.13</td>
</tr>
<tr>
<td>Cow</td>
<td>10</td>
<td>1.644</td>
<td>16.44a ± 1.03</td>
</tr>
<tr>
<td>Camel</td>
<td>10</td>
<td>1.199</td>
<td>11.99c ± 5.13</td>
</tr>
</tbody>
</table>

n = 3

a – c = means in the same column bearing similar superscript letters are not significantly different (P ≥ 0.05)
(P ≥0.05). the score of milk viscosity preference ranged between 4.0 and 3.8. According to the panelists liquid goat and camel milk (4.0) was more viscous (P ≤ 0.05) than fresh cow milk (3.8). Also the panelist had no reference (P ≥ 0.05) when they compared goat and camel milk viscosities. The score of overall acceptance ranged from 3.9 to 3.3. The cow liquid milk had the highest score (P ≤ 0.05) of acceptance (3.9), while the lowest acceptance score of fresh milk was for camel and goat were 3.4 and 3.3 respectively. Camel milk was second most acceptable among the milks of the three species.

4.7 Effect of spray drying on the sensory characteristic of milk powder

The sensory evaluation of milk powder made from different animal species is presented in table (4.7). The color score ranged between 3.5 and 3.8. The highest value (3.8) was showed by goat and cow milk powder while the lowest value (3.5) was showed by camel milk powder. Cow and goat milk powder had similar color (P ≥ 0.05) where as dried camel milk had significantly (P ≤ 0.05) lower color score than that of cow or goat milk powder. The score of flavor preference ranged from 2.2 to 3.6. The most preferred flavor score (3.6) was for cow milk powder while the least preference (2.2) was for dried camel milk. The flavor of dried cow milk was significantly (P ≤ 0.05) preferred by the panelists over that of goat or camel milk powder. The score of taste preference ranged between 2.9 to 3.7. The most preferred (P ≤ 0.05) taste was for dried cow milk, while the
Table 4.6: Sensory evaluation of liquid milk from different animal species

<table>
<thead>
<tr>
<th>Species</th>
<th>Color</th>
<th>Flavor</th>
<th>Taste</th>
<th>Viscosity</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat</td>
<td>4.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.3&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cow</td>
<td>4.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Camel</td>
<td>4.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

n = 3

a – c = means in the same column bearing similar superscript letters are not significantly different (P ≥ 0.05)
least preferred milk taste was for goat and camel milk powders. The panelist preferred significantly ($P \leq 0.05$) the taste of cow milk powder over that of goat and camel milk powders. The score of viscosity preference ranged between 3.5 and 3.6. According to the panelist cow and camel milk powder (3.6) was more viscous ($P \leq 0.05$) than goat milk powder (3.5). Also the panelist had no reference ($P \geq 0.05$) when they compared cow and camel milk powder viscosities. The score of overall acceptance ranged from 2.8 to 3.6. The cow milk powder had the highest score ($P \leq 0.05$) of acceptance (3.6), while the lowest acceptance score of milk powder was for goat and camel were 2.9 and 2.8 respectively. Goat milk powder was second most acceptable among the milk powders of the three species.
Table 4.7: Sensory evaluation of milk powder made from different animal species

<table>
<thead>
<tr>
<th>Species</th>
<th>Color</th>
<th>Flavor</th>
<th>Taste</th>
<th>Viscosity</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat</td>
<td>3.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cow</td>
<td>3.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Camel</td>
<td>3.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.8&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

n = 3

a – c = means in the same column bearing similar superscript letters are not significantly different (P ≥ 0.05)
CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

4.6 Conclusions

* Milk from the three species (goat, cow and camel) gave milk powder with a reasonable physico–chemical properties.
* All the milk powder made from the milk obtained from the three species was sensorially accepted by the panelist.
* None of the milk powder from the three species had a solubility index less than 90%.
* Cow’s milk gave the highest milk powder when compared with that of goat and camel.

4.7 Recommendations

Further investigation are needed to incorporated the effects of lactation period and seasonality on the properties and yield of whole milk powder from the three species.
REFERENCES


FAO (2002). FAO Investment Centre (FAO – I C) mission which visited Sudan from 05 May – 07 June to assist the government of Sudan in carrying out a socio – economic and marketing study on the dairy subsector.


