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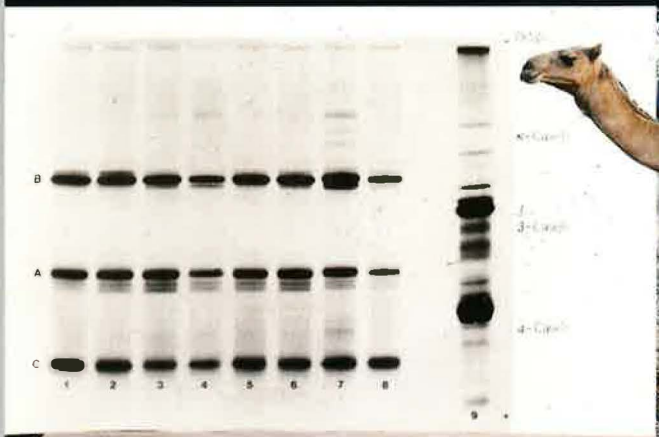
Properties and Products

Zakaria Farah



Camel milk
Properties and Products

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This work is dedicated to

my life companion Marianne

and

to my camel Haile, a patient, gentle childhood friend

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Preface

This book is the result of several years of studies on camel milk carried out at the Laboratory of Dairy Science at the Swiss Federal Institute of Technology, in collaboration with the Department of Food Technology and Nutrition at the University of Nairobi. I wish to thank the many friends, colleagues and students who helped me along the way. Some have been collaborators in the laboratory, others were nomads in the field who helped me with discussions and advice. I am particularly grateful to the late Prof. M.R. Bachmann for his constant support for my work and valuable advice, and Prof. Z. Puhan for his valuable critical comments on the final manuscript. I would also like to express my gratitude to Mr. J.O. Evans, Mrs. D. Atkins and Mr. T. Dyer for providing us with all the facilities to carry out the field work in Rumuruti and Ngare Ndare Camel Farm in Kenya. Last, but not least, our secretaries, Mrs. Christina Fasser and Mrs. Rosmarie Schlatter, deserve special thanks not only for typewriting and correcting the manuscript, but also for assisting me in numerous ways with valuable advice.

1 Introduction

The camel is raised in the arid and semiarid zones where feed resources are frequently scarce. It possesses remarkable abilities to exploit these limited resources as it is extremely well-suited for life under such conditions. It can endure hot climates and are active longer without water than any other domestic animal. The feed requirements of camels are modest, and, under drought conditions, they can reduce both their food intake and metabolism. Furthermore, they provide milk almost all the year round in quantities greater than other domestic animals living under the same conditions. The camel is also a means for transportation for many pastoralists, and provides meat and in some areas also hair and hide. In spite of these economic and ecological advantages the virtues of the camel are almost unknown outside the communities where it is used, and until now it has received less attention than other domestic animals. Much of the work on camels has been carried out by individuals with little institutional support. Topics such as anatomy, physiology, behaviour and, to a lesser extent disease, have attracted some attention while others of practical importance such as reproduction, breeding and husbandry have been largely neglected. This book attempts to fill a gap which exists in the literature. It provides a synthesis of existing knowledge on the chemical properties and physical characteristics of camel milk as well as technological problems associated with the utilization of camel milk. This has not been done before and it is true to say that no book of this nature, dealing especially with chemistry and technology of camel milk, has yet been published. The book is concerned entirely with the one-humped camel (*Camelus dromedarius*). The term „camel" should, therefore, be taken to refer to this species unless specifically stated otherwise.

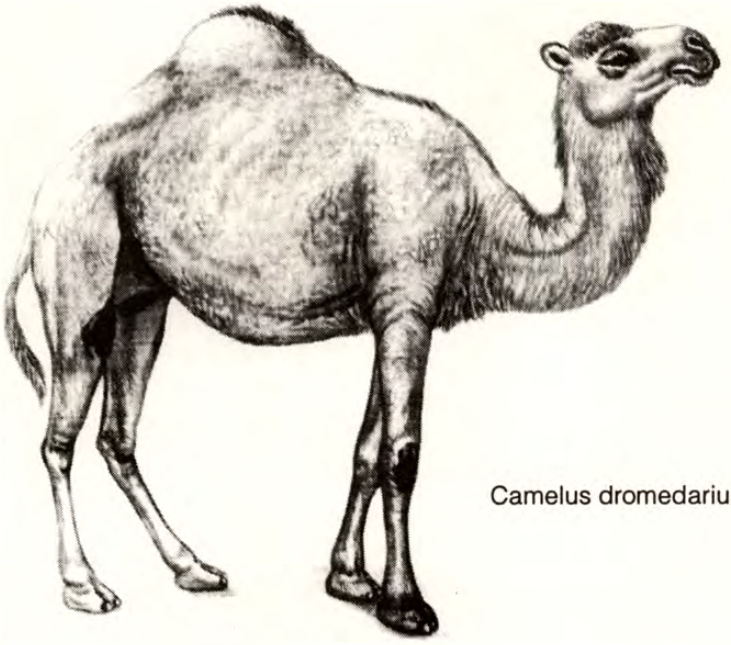
Before going into details on camel milk, a summary on the origin, distribution, physiological adaptation and traditional management of the animal itself is given. For comprehensive information on these aspects see Cauvet (1925), Schmidt-Nielsen (1964), Bulliet (1975), Gauthier and Dagg (1981), Wilson (1984), Yagil (1985) and Schwartz and Dioli (1992).

1.1 Origin and domestication

Camels belong to the family Camelidae (Fig. 1.1) and, thereby, to the suborder Tylopoda. Tylopoda themselves belong to the order

Artiodactyla or cloven-footed animals. The family Camelidae contains the genera *Camelus* (old world camel) and *Lama* (new world camel). The Camelidae originated in North America, where the earliest fossil remains have been found. The genus *Camelus* migrated from North America in the late Tertiary across the then existing landbridge to Asia and Africa. The *Lama* on the other hand reached South America in the ice age across the Central American landbridge. The genus *Camelus* includes the one-humped dromedary (*Camelus dromedarius*) and the two-humped bactrian (*Camelus bactrianus*). The term dromedary is derived from the Greek word „dromados" (run) and, in the strict sense, is used for riding camels. The name „bactrian" for the two-humped camel refers to the area „Baktria" in North Afghanistan where this type of camel is thought to have originated . The dromedary is slim, long-legged, short-haired and its habitat is warm arid and semi-arid areas. The bactrian is stockier, short-legged and has a thicker and longer coat than the dromedary. It mainly occurs in cold and mountainous areas (Simpson 1945; Zeuner 1963).

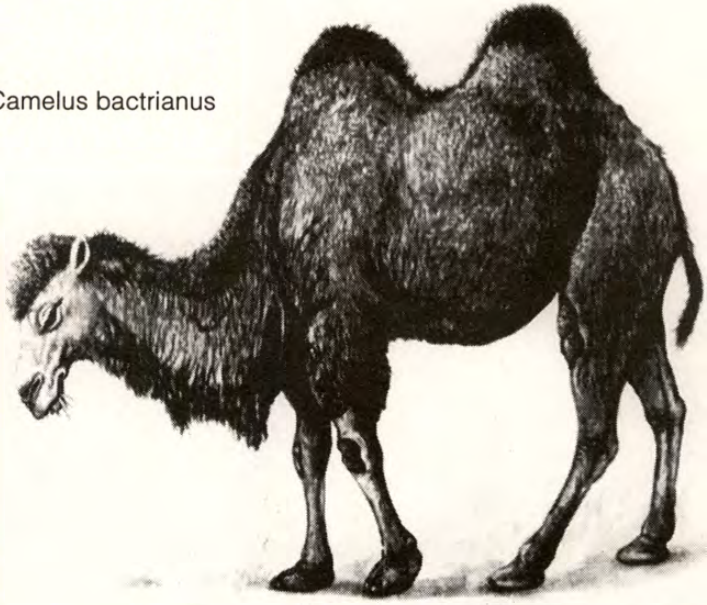
Fig. 1.1 ***The family camelidae***



Camelus dromedarius

Lama

Camelus bactrianus



Dromedary and bactrian can interbreed. Crossing a dromedary female with a bactrian male results in the F1-generation in a single-humped hybrid, which is found mainly in Iran and Turkey. The products of the crossing are stronger than the parents and are thought of as good pack animals. Crossing a bactrian female with a dromedary male is also possible, but not common as the offspring are less robust and, on account of their extended hump, have an unattractive appearance (Gray 1971; Kolpakov 1935). Where and when

camels were first domesticated has not yet been established. The oldest written reference to camels is in the Bible, where it is stated that Abraham sent his servant with ten camels from Palestine to Mesopotamia to seek a bride for his son Isaac. Today it is assumed that this happened around 1800 BC. It is, however, generally thought that domestication of camels had begun in 2000-4000 BC with dromedaries being kept principally in Central and Southern Arabia and bactrians in the border area between the Iranian province Khursan and Turkmenistan in the former USSR (Bulliet 1975).

1.2 Present distribution and economic potential

In just a few centuries camels have spread from where they originated into several areas where they found great use as important pack and milk animals. The two-humped bactrian extended its range over broad regions of Asia, in the East to the Northern China, and in the West to Asia Minor and Southern Russia. The dromedary spread chiefly in the wake of the campaigns of conquest of the Islamic Arabs to East and North Africa as well as South West Asia. With few exceptions, camel husbandry is concentrated in areas with short periods of precipitation and long hot dry periods. Bactrians are mainly kept in areas where the annual mean temperatures do not exceed 21°C. Attempts have been made to keep camels in areas outside the regions where they originated. In Spain, Italy and the United States they were used as mounts for the police and army. When the desert areas of Australia were being opened up, camels were used as draught animals. With the development of motorised road transport, the introduced camels were no longer needed and they were left to their own devices. The camels introduced in Europe and United States died out. In Australia on the other hand, where large camel herds were introduced, there still exist some 15 000 to 20 000 feral camels (Yagil 1982; Wilson 1984).

According to FAO (1989) statistics (Table 1.1) there are about 18 million camels in the world, of which 14 million are found in Africa and 4 million in Asia. Of this estimated world population, 16 million are believed to be one-humped camels and 2 million two-humped. Approximately 11 million dromedaries, representing two thirds of the world's camel population, are in the arid areas of Africa, particularly in North East Africa, i.e. Somalia, Sudan, Ethiopia and Kenya. The majority of camels in this region is kept by pastoralists in subsistence production stystems. In Somalia where the ratio of man to camel is one to one, camel milk is one of the main compo-

nents of the human diet. It is estimated to contribute between 25 and 30 % of the main annual caloric intake of the household members. Camel milk also provides cash from sales, contributing 15-20 % of total household cash income (Abdullahi 1991). Sale of live camels, usually males and unproductive females for slaughter, is very common in East Africa. There is also a growing export trade of slaughter camels to the Arabian Peninsula.

Table 1.1 ***Estimated camel populations of Africa and the world (FAO 1989)***

Country	**Camel population (in 1000)**
Africa:	
Algeria	147
Chad	26
Djibouti	405
Egypt	95
Ethiopia	1000
Kenya	780
Libya	75
Mali	198
Mauritania	718
Morocco	20
Niger	350
Nigeria	18
Senegal	6
Somalia	6000
Sudan	3000
Tunisia	205
Upper Volta	5
West Sahara	86
Other regions:	
Afghanistan	290
China	1040
India	1174
Iraq	232
Mongolia	615
Pakistan	819
Saudi Arabia	108
Former USSR	230

From a global perspective, the economic significance of camel production is minimal in comparison with that of other domestic animals (Table 1.2). Nevertheless, in Africa, especially in East Africa, the camel population makes a significant contribution to national economies. However, it is difficult to evaluate this economic contri-

bution as most of the camel products are consumed within the producer community and traded in the informal sector.

Owing to the increasing human population and declining per caput production of food in Africa, there is an urgent need to develop marginal resources, such as arid land, and optimize their utilization through appropriate livestock production systems of which camel production is the most suitable without doubt.

Table 1.2 ***Numbers of domestic ruminants and camels in the world (FAO 1989)***

Species	World million head	Whole Africa million head	East Africa million head
Cattle	1264	181	72
Sheep	1173	200	65
Goats	520	167	63
Camels	18.9	14.2	11.5

1.3 Physiological adaptation to the desert environment

The habitat of the camel is characterised by large variations in temperature and scarce irregular rainfall. In the course of evolution, the camel adapted in various ways to the conditions of that environment. In the following, some of the particular mechanisms of the adaptation of the camel are briefly described. For more comprehensive information, the reviews of Schmidt-Nielson (1964) and Yagil (1985) are recommended.

The hump contains fat and metabolism of fat yields an amount of water greater than the weight of the fat. Since oxidation requires oxygen the necessary ventilation of the lungs involves a loss of water vapour. This loss exceeds the amount of water formed.

The body temperature of the camel is quite variable, and when the camel is deprived of water the daily fluctuations may exceed 6° C. These fluctuations are important in the water balance for two reasons: Firstly, as body temperature rises during the hot day, water otherwise used to keep the temperature down remains unexpended. The excess heat is stored in the body and is dissipated to the cool environment at night without use of water. Secondly, an elevated body temperature reduces the heat flow from the hot environment

to the body, and, therefore, reduces the amount of water needed to prevent further temperature rise.

The camel can withstand considerable dehydration. In a hot environment it can tolerate a loss of at least 27 % of the body weight, twice the dehydration that brings other mammals into lethal explosive heat rise. The limit for dehydration of the camel is unknown. When the camel becomes dehydrated the loss of water is not accompanied by a proportional loss in plasma volume. The maintenance of a high plasma volume facilitates circulation, which is one of the first functions to suffer during dehydration of other animals in hot environments.

In a hot environment the fur is an important barrier against heat gain from the environment. When animals with and without fur are compared under otherwise identical conditions it is found that less water is used by unshorn camels. The camel does not pant, but does sweat. Sweat is produced in moderate quantities, but the fur is not wetted and appears dry. Water evaporates from the surface of the skin rather than from the surface of the fur, an important factor in water economy.

The camel has powerful kidneys which can produce a concentrated urine. Adequate studies of the concentrating ability of the kidney are lacking. Under certain circumstances urea can be withheld from excretion and be resynthesized into protein by the microbial flora of the rumen (Schmidt-Nielson et al. 1956b; Macfarlane 1968).

1.4 Traditional husbandry and management

In the literature some studies have been reported which deal to a lesser or greater extent with camel husbandry and the traditional management practices of the nomads. The most important of these studies are those by Lewis (1961), Nicolaisen (1963), Spencer (1973), and Cole (1975). Camels are held by nomads in arid regions and are not commonly found in areas where agriculture predominates. Pastoral land in arid areas is mainly covered with annual grass, acacias, euphorbias and dwarf bushes. The annual rainfall varies between 100 and 400 mm, the amount of rain varying from year to year and the rains being restricted to widely separated areas. This type of pasture permits only extensive types of animal production. Because of its high mobility, its modest fodder requirement and its water regulation perfectly adapted to the environment, the camel is better suited than any other domesticated animal to use this type of pasture (Fig. 1.2, 1.3).

Fig. 1.2 ***Watering of camels***

Fig. 1.3 ***Camel browsing***

In the nomadic economy, camels serve primarily as milk producers but are also used as pack and meat animals. This subsistence economy is based on two main traditional management patterns:

Utilization of pasture according to defined annual cycles

For optimal utilization of scarce feed and water resources nomads graze their animals according to an annual cycle. The camels are divided into two categories according to their economic utilization

in the rainy and dry season. The first category consists of milking animals, as well as the 2 to 4 year-old animals. The second category is composed of males and females not giving milk. The first category grazes during the rainy and dry seasons in the immediate vicinity of the family to ensure milk supply. During the dry season this category also contains some pack animals, most of which are castrated. They are used to transport the dwellings as well as to fetch food and water from a great distance. The second category grazes in the rainy season at a distance of at most two hours from the kraals. Shortly after the end of the rainy season, the migration starts and the position of the kraals is changed according to the fodder and water situation. The camels are accompanied by young unmarried herdsmen. Often, the herdsmen dispatch a small reconnaissance group in advance in order to evaluate the grazing conditions, but also to establish whether other groups are already grazing their herds there. According to the nomads, camels can survive in times of extreme need for up to 30 days without water. This depends, however, on the grazing conditions and prevailing temperatures.

The salt requirement of camels is very high, being six to eight times higher than that of other domestic animals (Wilson 1984) and can only partly be satisfied by grazing. When the herdsmen observe that the camels are restless and have reduced appetite and milking performance, they take this to be a sure sign of salt deficiency. The camels are then driven to salty water sources and watered repeatedly. Alternatively, salt-containing earth collected from other areas is given to the animals.

Manipulation of the herd structure

It is often difficult to make meaningful statements on the numbers of camels owned by a nomad family. A family can possess a small number of animals because it has only recently separated from a large family, or become independent by division of an inheritance. Some years later, the situation will have completely changed. Such variations in the size of herd also arise from receipt or paying out of blood money or bride prices or through natural causes. Studies of many nomadic people in several countries show that female animals constitute 69 to 80 % of a camel herd. Table 1.3 shows the structure of 35 camel herds consisting of 80 to 100 camels each, which were observed over two years in Somalia (Hussein 1987a). Similar herd structures were established in Kenya (Spencer 1973), in Sudan (Wilson 1978) and with Tuareg groups in Mali (Swift 1979).

The high number of female animals is needed to satisfy the large milk requirement of the nomad economy. Male animals, separated from the herd, are used as pack animals, serve as gifts or are slaughtered.

Table 1.3 ***Structure of 35 observed herds in Somalia (Hussein 1987)***

Class of stock	**Share in the herd - %**
Milk camels	22
Pregnant camels	31
Dry camels	18
Castrates	8
Young males (less than 2 years)	9
Young females (less than 2 years)	11
Males for reproduction	1

Reproduction of the herds is achieved by selection of suitable male camels. According to several personal communications, these should have the following characteristics:

- The bull or its father should have had predominantly female progeny with good milk performance
- It should be fully grown and strong
- It should be a good fighter able to overcome other males

It would be difficult to evaluate to what extent these selection criteria influence the quality of the progeny. One restriction arises from the fact that only the characteristics of the father, and not the characteristics inherited from the mother, are taken into account in the selection.

In general, breeds of camels are not as highly differentiated as breeds of other domesticated species. In most camel rearing societies, breed classifications are based on names of the clan as well as on the geographical localities where these camels are raised, rather than upon phenotypical characteristics. An exception is Somalia, where according to Hussein (1987b) three breeds of camels which are distinct by appearance exist. These are according to Somali terminology *Hoor, Siifdaar* und *Eyddimo*. The main differences between the three types of camels are summarized in Table 1.4.

Table 1.4 ***Camel breeds in Somalia (Hussein, 1987b)***

	Hoor	**Silfdaar**	**Eyddimo**
Size	Small/compact	Tall/light	Tall/heavy
Weight	small	average	heavy
Colour	ash/white	grey	mostly white
Production focus	milk	dual	dual
Milk daily (litres)	8	6	4
Lactation period (months)	8-16	12	6-10
Milk per lactation (litres)	2050	1500	1000
Milk let down	difficult	easy	easy
Maturity age (years)	5-6	6-7	7-8

Mating of camels takes place in the rainy season, seldom in the dry season (El-Amin 1979; Yagil and Etzion 1980c). The male covers the female repeatedly until she demonstrates signs of pregnancy. A sure sign of pregnancy according to Somali nomads is that a female approached by a male camel holds her tail erect, waves it to and fro and urinates slightly. A pregnant camel reacts in the same way when the herdsman approaches her holding a stick (Hartley 1979, and personal communication 1988). The gestation period ranges from 308 days (Schmidt 1973) to 440 days (Grzimek 1968). However, the average length of gestation period given in the literature is 390 days (Yagil 1985). Normally camels are sexually mature at the age of 4 to 5 years. A female camel accordingly has her first calf at 6 to 7 years of age. Under normal conditions, a female camel, giving birth every other year, will have 8 to 10 calves during her lifetime, which is on average 25 to 30 years (Yassin and Abdul Wahid 1957; Williamson and Payne 1978).

2 Camel milk

In many arid areas, camels play a central role as milk suppliers. The comparative advantage of the camel as a dairy animal over the other species in the same environment is difficult to quantify; however, it is widely recognised that in absolute terms, the camel produces more milk and for a longer period of time than any other milk animal held under the same conditions.

In East Africa, where 60 % of the world camel population are held, the consumption of camel milk is not limited to only the pastoral nomads, but camel milk is also commercialised and sold in the urban areas (Schwartz and Dioli, 1992).

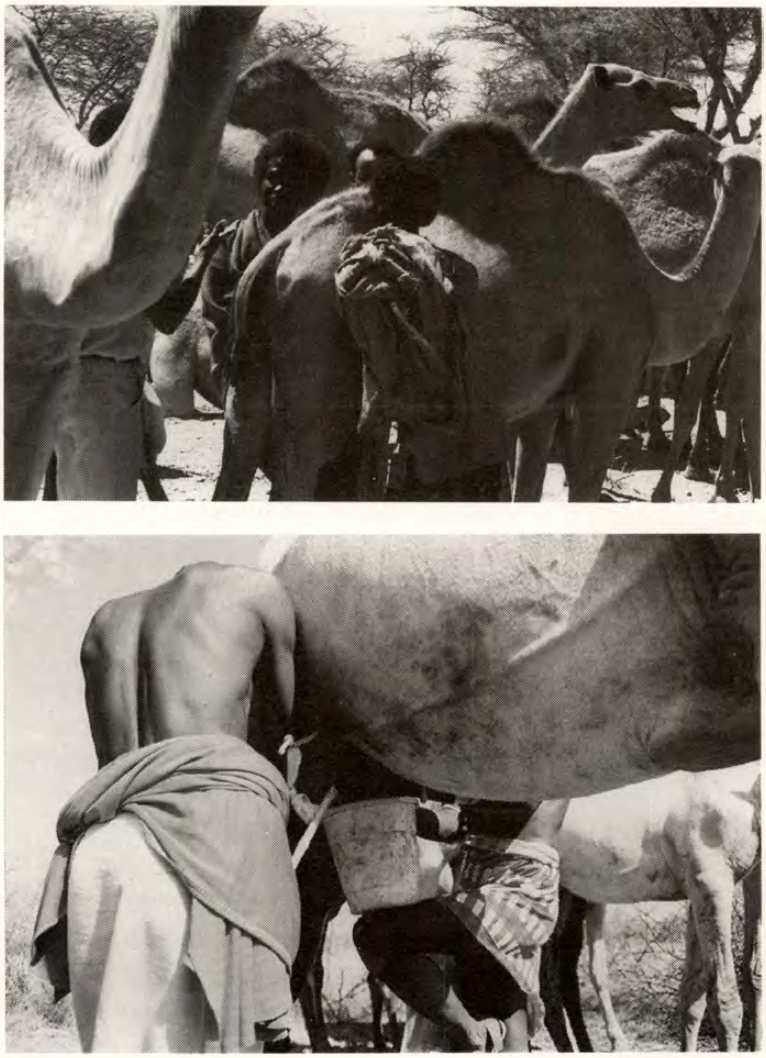
Studies on the camel milk market in Somalia (Hashi 1988) showed that camel milk outweighed other milk types in rural pastoral areas during the dry season. Similar observations were made by the Land Resources Development Center (LRDC) (1986). Hashi and Cianci (1985) reported on two types of camel-oriented dairy systems in Somalia: One case consisted of wide ranging nomadic herders, who from time to time during their seasonal migratory movement, pass through the „milk catchment areas" surrounding settlements where they sell their milk surplus. The other case was more intensive camel dairying, based on a range of reserves established around towns. The reserves serve as camel catchment areas. A herdsman would keep three to four milk camels in such a reserve and pay a small fee. He could then regularly market the milk through urban milk traders who collect milk from areas as far as 90 km from the town.

These traditional dairy systems can be the basis for a dairy processing camel milk, particularly in countries where large camel populations are found. Certainly, the wide dispersal of pastoralists in the arid zone would make a formal milk collection, processing and marketing system difficult to establish and to maintain. However, before the difficulties can be identified and overcome, the knowledge of camel milk itself has to be broadened. In the following sections, published data on yield, composition, chemical characteristics and technological properties of camel milk are summarised and some of the gaps and contradictions in the existing state of knowledge are emphasized.

2.1 Milk yield

Camels in most pastoral societies are milked by men (Fig. 2.1). Because of the height of the udder the milking is done standing with one knee raised to support the milking bowl.

Figure 2.1 ***Milking of camels***



In general both udder halves are milked at the same time by two herdsmen but sometimes one half of the udder is milked and the other one left for the calf. Milking camels are usually very docile and gentle animals which accept milking easily.

Before milking, the calf is allowed to suckle until the milk starts to flow and the camel can be milked. Without this stimulation, the dam cannot be milked. If a calf dies, the dam dries up if milking is not stimulated. Often it is sufficient for the dam to see the skin of her calf for milk secretion to be stimulated.

Camels, particularly young ones, quite often refuse to nurse their calves. When this happens, they must be forced to accept their calf, otherwise milk production would cease within days. Pastoralists have developed several elaborate techniques to reach this objective, all based on the same principle (Schwartz and Dioli 1992), namely causing increasing degrees of discomfort or even pain to the mother which will absorb her attention to such an extent that she „forgets" to reject the calf. After the calf has suckled a few times, the device is removed and in most cases the relief is so strong that the mother will accept the calf permanently.To increase the amount of milk taken for human consumption, the milk suckled by the calf is controlled to some extent. Calves are with their mothers during the day and are kept separately at night. To prevent calves from suckling at pasture during the day it is common among Somali nomads to tie up one or more teats with special strings.

In Table 2.1 data on milk yields of camels are presented. For better comparison, milk yields are calculated for a lactation period of 305 days. Daily yields between 3 and 6 kg with total yields between 1500 and 2500 kg produced within a lactation period of 9 to 18 months are most likely to be the common range of lactation performance. Such yields may not sound very impressive when compared with those of dairy cattle in moderate temperature zones of the industrialized countries. Considering, however, the local feed base in arid areas which is frequently inadequate, such yields are impressive, and indicate that the camel is a potentially better milk animal than African Zebu cows. The daily milk yield of those cows held under the same environmental conditions varies between 0.5 and 1.5 kg (Kiwuwa 1973).

Table 2.1 ***Average milk yields of camels***

Country	Daily yield *kg*	Lactation length *months*	Calculated yield for 305 days *kg*	Reference
Egypt	3.5-4.5	9	1068-1373	El-Bahay (1962)
Ethiopia	5-13	12-18	1525-3965	Knoess (1977)
India	7-18	15	2105-5551	Rao (1974)
Kenya	2-12	11-16	610-3660	Field (1979)
Pakistan	8-10	12	2440-3050	Knoess (1979)
Somalia	3-9	9-18	915-2745	Hartley (1979)
Sudan	5-10	10-12	1525-3050	El-Amin (1979)
Tunisia	4	12	1220	Bürgemeister (1974)

It is difficult to estimate the daily milk yield of a camel under pastoral conditions. On the one hand, throughout lactation, the calves are still suckling and, therefore, the actual volumes of milk secreted are higher than the figures presented in the table. On the other hand, milking frequency varies among the different pastoral groups. Camels may be milked once a day among the Murah of Arabia (Cole, 1975), 2 to 4 times among the Somali (Bremaud, 1969; Hartley, 1979) and the Rendile of Kenya (Spencer, 1973) and even as many as six or seven times a day among the Afar of Ethiopia (Knoess, 1977). The Afars may also leave their animals unmilked for a whole day, which may account for sporadic very high daily yield estimates.

It is known that bovine somatotropin (bST) increases milk yield by 15 to 25 % in dairy cow without changing the quality of milk (McBride et al. 1988; Baumann et al. 1989). Zia-Ur-Rahman and Straten (1994) studied the effect of bST on yield and composition of milk in eighty lactating Pakistan camels from the Punjab area. The study lasted for 13 days. On day one after injection of bST, camels responded with increased milk yields which continued until day 13. Maximum response was observed from days 9 to 12. Milk yields of individual camels injected with bST ranged from 5 to 9 kg/day versus it was 3 to 6 kg/day in the control group. Neither fat nor protein percentage in milk was affected by the use of bST. The result of this short term study shows that bST gives a positive milk yield response in camel.

In general, the factors affecting milk yield are those common to all dairy animals: nutrient supply, health care and genetic potential. The first two factors offer feasible ways of increasing milk yield provided that the respective services are available and their applica-

tion is profitable. Improving the genetic potential for milk production in African camels is possible. However, it requires structured cross-breeding programmes including herd selection, disease control, milk recording, progeny testing and improved management. To build up a nucleus herd for such a programme, high yielding dairy breeds reported in countries such as Saudi Arabia and Pakistan (Knoess et al. 1986) can be used. Nevertheless, a cross-breeding programme is a very long undertaking and can be realized only through joint national and international collaboration. Moreover, it has by no means been ascertained that the improved genetic potential can be exploited in the pastoral management system.

2.2 Composition of camel milk

Some published data on the composition of camel milk are summarised in Table 2.2. The differences among the various sets of data undoubtedly reflect differences in breed and state of lactation of the animals sampled, in sampling procedures and most probably in analytical procedures as well. The main components of camel milk will be discussed in detail in section 3. In addition to data presented in Table 2.2 some scattered information on camel milk should be also mentioned here.

Table 2.2 ***Gross composition of camel milk***

Dry matter *g/100ml*	**Fat** *g/100ml*	**Lactose** *g/100ml*	**Protein** *g/100ml*	**Ash** *g/100ml*	**Reference**
9.8	3.2	4.2	2.7	0.6	Desai et al. (1982)
14.4	5.5	3.4	4.5	0.9	Knoess (1977)
11.9	3.6	4.4	3.0	0.8	Sawaya et al. (1984)
13.0	3.3	5.6	3.3	0.8	Gnan and Sheriha (1986)
13.4	3.2	4.8	4.0	0.7	Abdel-Rahim (1987)
11.3	3.3	4.7	2.7	0.9	Abu-Lehia (1987)
11.0	3.5	3.9	2.5	0.8	Hassan et al. (1987)
14.2	3.8	5.5	4.0	0.8	Abu Lehia et al. (1989)
12.2	3.2	5.2	3.1	0.8	Farah and Rüegg (1989)
11.9	3.2	4.5	3.4	0.8	Mehaia and Al-Kahnal (1989)
13.4	3.6	5.5	3.3	0.8	Bayoumi (1990)
11.0	3.2	4.2	2.8	0.8	El-Amin and Wilcox (1992)

Camel milk is generally opaque-white, has a sweet and sharp taste, and can sometimes be salty. The changes in taste are caused by the type of fodder and availability of drinking water. The pH of camel milk ranges from 6.5 to 6.7 with an average pH around 6.6. The density varies from 1.025 to 1.032 with an average of 1.029. Both values, pH and density, are lower than those of cow milk (Rao et al. 1970; El-Bahay 1962; Shalash 1983; Sawaya et al. 1984 and Farah and Bachmann 1987). The buffering capacity of camel milk was studied by Al-Saleh and Hammad (1992). The maximum buffering capacity of skim milk was at pH 4.95. Skim cow milk showed higher buffering capacity at pH 5.65.

The ability of camel milk to inhibit the growth of pathogenic bacteria and the relationship of its lysozyme content to the inhibitory effect have been studied by Barbour et al. (1984). 20 of 200 samples collected from individual camels inhibited growth of one or more of the six pathogenic test organisms. The milk samples with inhibitory property scored zero in the California mastitis test. The lysozyme content of the 20 samples showing growth inhibition was 648 µg/100 ml, thus being ten times higher than the average of 38 samples (62.6 µg/100 ml) showing no inhibitory effect. The reported average lysozyme content of human milk is 40 000 µg/100 ml and of cow milk 120 µg/100 ml (Chandan et al. 1968). The significantly very high level of lysozyme in camel milk is of importance for the storage of milk and needs further investigation.

El-Agamy et al. (1992) extracted lysozyme (Lz), lactoferrin (Lf), lactoperoxidase (Lp), immunoglobulin G and immunoglobulin A from camel milk. The activity of these protective proteins was assayed against *Lactococcus lactis* subsp. *cremoris, Escherichia coli, Staphylococcus aureus, Salmonella typhimurium* and rotavirus. The antibacterial activity spectrum of camel milk Lz was similar to that of egg white Lz but different from bovine milk Lz. Bovine and camel milk Lf antibacterial activity spectra were similar. The camel milk Lp was bacteriostatic against the Gram-positive species and bactericidal against Gram-negative species. The immunoglobulins had little effect against the bacteria but high titers of antibodies against rotavirus were found in camel milk.

One of the important factors which affects camel milk composition is the amount of water available to the animal. Yagil and Etzion (1980) examined the effects of the lack of drinking water on camel milk. While the diet remained unchanged throughout the year, great changes in water content of milk were found. During the experi-

ment, the camels were allowed to drink water *ad libitum* only during the winter. From spring until the end of summer, however, dams and calves were allowed to drink only once a week for one hour. With water freely accessible, the water content of the milk was 86 %, and when drinking was restricted, the water content of milk rose to 91 %. These changes reflect the range presented in the literature, indicating the importance of when the milk was sampled by the various investigators. This study also shows that the lactating camel loses water to the milk in times of drought. This could be a natural adaptation in order to provide the necessary fluid to prevent dehydration of the calf.

The colostrum of camels is white and slightly more dilute, than bovine colostrum (Rao et al. 1970; Yagil and Etzion 1980). Only fragmentary data are available on the composition of camel colostrum. The most complete data are those reported by Sestucheva (1958) and Abu-Lehia et al. (1989) for Russian and Saudi camels. Sestucheva studied 10 Kazakhstan camels. The first colostrum obtained 3 hours *post partum* contained on average 30.4 % total solids, 0.20 % fat, 19.4 % protein, 7.2 % lactose and 3.8 % minerals. During the first two days of lactation, the solids content fell to 18.4 %, mainly due to the decline of total proteins to 3.6 % and of minerals to 0.1 %. The fat content increased up to 5.8 % whereas the lactose level was practically unchanged. The composition then remained fairly constant until the 10th day, when the experiment ended.

Abu-Lehia et al. (1989) examined the colostrum of 10 Saudi camels (Majaheem breed) during their first season of lactation up to the 10th day *post partum*. At parturition, the content of total solids, fat, protein, lactose and minerals were 20.5 %, 0.20 %, 13.0 %, 2.7 %, 1.0 % respectively. After 3 days, total solids decreased to 13.6 %, protein to 4.7 % and minerals to 0.8 %. On the other hand, the fat content rose to 1.5 % and lactose to 4.4 %.

Transformation from colostrum to a composition within the range of normal milk was reached after one week. From the present data it appears that the composition of camel milk colostrum and the rate of its change are similar to those reported for cow milk (Webb and Johnson 1974).

Although it is widely accepted that colostrum, owing to its high content of immunoglobulins, is vital for the immunisation of the newborn calf, in most countries where camels are kept, the colostrum is

considered unsuitable for the calf and is milked onto the ground, leaving only a relatively small quantity for suckling to the calf. It is, therefore, not surprising that the mortality of new-born camels is in many areas very high (Yagil 1985).

3 Main components of camel milk

The majority of the studies conducted on camels concentrate on anatomical features and physiological adaptation to desert conditions. Information about camel milk is mostly limited to some data on gross composition (Table 2.2). Studies on individual components and their physico-chemical characterisation have received up to now very limited attention. The present work attempts to place the scarce information available on camel milk components into a coherent framework. Emphasis is given to comparison with bovine milk. This is understandable in as much as bovine milk has been the subject of intensive research over a long period and, although many areas of uncertainty still exist, the general physico-chemical properties of all main and even a number of minor components of bovine milk are well established.

3.1 Protein

3.1.1 Overall composition

The distribution of N-fractions in camel milk from four different regions is presented in Table 3.1. All authors used the method of Rowland (1938) modified by Aschaffenburg and Drewry (1959) for determining the N-fractions. The protein content is calculated from N x 6.38.

Table 3.1 ***Nitrogen distribution of camel milk***

Casein	Whey protein	CN	WPN	NPN	Reference
g/100 g milk		*% of TN*			
2.2	0.8	74	21	4.6	Urbisimov et al. (1983)
1.9	0.9	72	22	6.2	Abu-Lehia (1987)
2.1	0.7	76	17	6.7	Farah et al. (1989)
2.3	1.0	71	23	5.8	Bayoumi (1990)
2.2-3.8	0.5-0.9	72-78	17-22	4.7-5.5	cow milk

The average casein and whey protein contents in camel milk vary between 1.9 and 2.3 % and between 0.7 and 1.0 % respectively. The values of casein nitrogen (CN), whey protein nitrogen (WPN)

and non-protein nitrogen (NPN), expressed as percentage of the total nitrogen (TN), range between 71 and 76 %, 17 and 23 % and 4.6 and 5.8 % respectively. The results in Table 3.1 generally indicate that the distributions of protein and N-fractions in camel milk are similar to those in cow milk. Camel milk, however, seems to contain a somewhat higher amount of NPN than cow milk.

Recent data on amino acid composition of camel milk protein are presented in Table 3.2. The amino acid spectrum appears in general to be similar to that of cow milk protein.

Table 3.2 ***Amino acid composition of camel milk proteins***

Amino acid	**Camel[1)] % of protein**	**Camel[2)] % of protein**	**Cow[3)] % of protein**
Alanine	2.8	2.7	3.5
Arginine	3.9	3.8	3.7
Aspartic acid	7.6	6.4	7.9
Cysteine	-	-	-
Cystine	1.0	0.6	0.7
Glutamic acid	23.9	19.5	21.8
Glycine	1.7	1.3	2.1
Histidine	2.5	2.7	2.8
Isoleucine	5.4	5.0	6.4
Leucine	10.4	9.5	10.4
Lysine	7.0	7.1	8.3
Methionine	2.5	3.6	2.7
Phenylalanine	4.6	5.6	5.2
Proline	11.1	11.1	10.0
Serine	5.8	4.2	5.6
Threonine	5.2	4.3	5.1
Tryptophan	1.2	-	1.4
Tyrosine	4.5	4.0	5.3
Valine	6.1	6.9	6.8

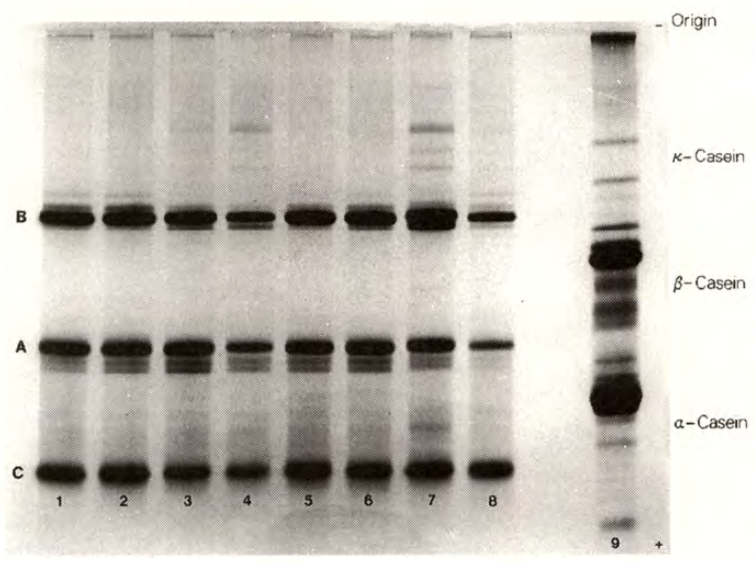
1) Sawya et al. (1984)
2) Mehaia et al. (1989)
3) Renner (1991)

3.1.2 Casein fractions

According to the 5th revision of the Nomenclature of proteins of cow milk (Eigel et al. 1984), caseins were defined as phosphoproteins which precipitate from raw skim milk upon acidification to pH 4.6 at 20° C, and the individual caseins were defined

according to their electrophoretic mobility in alkaline polyacrylamide or starch gels. Following this definition, camel milk proteins have been separated by means of polyacrylamide gel electrophoresis (PAGE) (Farah and Farah-Riesen 1985). Samples of milk of six individual camels as well as their pooled milk were compared with cow milk. As shown in Fig. 3.1, camel milk protein has in general considerably lower electrophoretic mobility. The electrophoretic pattern showed three main bands which were designated as B, A, C according to their electrophoretic mobility. The three bands can possibly be regarded as homologous to bovine β-casein, α-casein and whey proteins respectively.

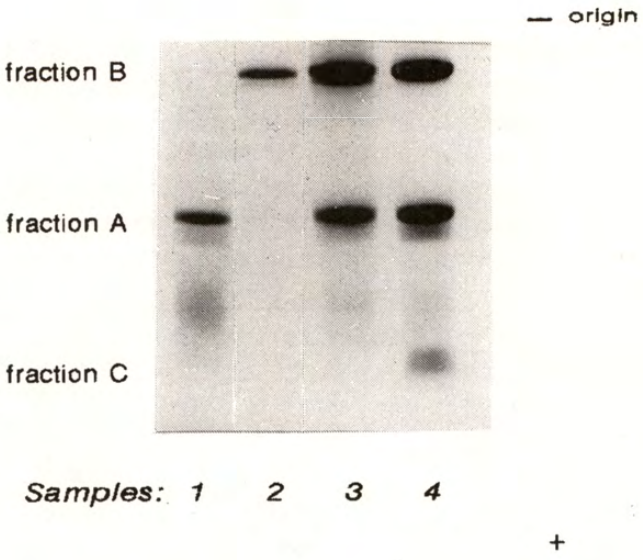
Figure 3.1 ***Polyacrylamide gel patterns of camel milk and cow milk; 1, 2, pooled camel milk; 3, 4, 5, 6, 7, 8, milk from six individual camels; 9, cow milk (Farah and Farah-Riesen 1985)***



Two caseins, homologous to bovine α- and β-casein, have been isolated from camel casein. The casein fraction was obtained by acid precipitation following the same procedure as for cow milk casein.

Fig. 3.2 shows the electrophoretic patterns of camel milk, and acid-precipitated camel casein. Fraction B was isolated according to Aschaffenburg's (1963) β-casein preparation method, and fraction A was isolated as α-casein by the urea method of Hipp et al. (1952). Fractions A and B can be considered as possibly homologous to bovine α- and β-casein. Fraction B (β-casein) clearly shows a single strong band. Fraction A (α-casein) shows one strong band and some diffuse slow moving bands. In general, α-casein occurs in bovine milk as a mixture of several genetic variants of α_{s1}, α_{s2} etc. The fractionation method applied here suggests the strong band to be similar to bovine α_{s1}-casein, and the diffuse band moving behind presumably to α_{s2}-casein. No bands of κ-casein could be detected in the electrophoretic pattern. The molecular weights of the camel casein fractions were estimated by means of sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) to be 32 000 daltons for fraction B (β-casein) and 35 000 for fraction A (α-casein). These values are higher than those of bovine caseins which are usually reported in the literature as 24 000 for β-casein, 22 000 to 25 000 for α_{s1}-casein and 25 000 for α_{s2}-casein (Eigel et al. 1984).This first attempt to separate camel milk casein was followed by the work of Larsson-Raznikiewicz and Mohammed (1986). They isolated four casein fractions by ion exchange chromatography and identified them by polyacrylamide gel electrophoresis. Analysis of the amino acids and of phosphorus revealed that proteins analogous to the α_{s1}-, α_{s2}-, β- and κ-caseins of cow milk occur in camel milk. For camel milk α_{s1}- and β-casein dominated whereas α_{s2}-casein appeared as a diffuse band. No protein band corresponding to κ-casein was present on PAGE but it could be isolated by ion exchange chromatography and identified as „homologous" to bovine κ-casein on the basis of its amino acid composition. Furthermore, the α_{s1}- and β-casein of camel milk were phosphorylated to about the same extent as in bovine milk. α_{s2}-casein was more heavily phosphorylated than the corresponding bovine casein.

Figure 3.2 ***Polyacrylamide gel patterns of camel milk and camel milk casein fractions: 1, fraction A; 2, fraction B; 3, whole camel casein; 4, camel milk (Farah and Farah-Riesen 1985)***



In Table 3.3 the amino acid compositions of the different casein fractions isolated by ion exchange chromatography are given. It shows that there are close similarities in the amino acid composition between the camel and bovine casein fractions. The molecular weights of camel casein estimated from SDS-PAGE were 27 000, 31 000 and 25 000 for β-, α_{s1}- and α_{s2}-casein respectively. These M.W-values differ from those obtained by Farah and Farah-Riesen (1985) for camel α-casein and, particularly, for β-casein.

Table 3.3 ***Amino acid composition of camel casein (Larsson-Raznikiewicz and Mohammed 1986)***

Amino acids	**β-casein**		**κ-casein**		**α_{s1}-casein**		**α_{s2}-casein**	
	camel	cow	camel	cow	camel	cow	camel	cow
	%	%	%	%	%	%	%	%
Alanine	2.9	2.4	4.8	8.3	3.0	4.5	2.9	3.9
Arginine	1.9	1.9	2.7	3.0	4.9	3.0	1.8	2.9
Aspartic acid	3.8	4.3	6.2	7.1	9.1	7.5	6.5	8.7
Cysteine	0.0	0.0	0.6	1.2	0.0	0.0	1.0	1.0
Glutamic acid	19.5	18.7	17.7	16.0	20.9	19.6	21.8	19.3
Glycine	1.2	2.4	2.2	1.2	2.3	4.5	1.9	1.0
Histidine	1.8	2.4	1.9	1.8	2.3	2.5	2.7	1.4
Isoleucine	5.7	4.8	6.9	7.1	6.2	5.5	5.3	5.3
Leucine	10.8	10.5	7.2	4.7	8.0	8.5	5.1	6.3
Lysine	5.9	5.3	5.6	5.3	7.3	8.0	10.6	11.6
Methionine	2.9	2.9	1.5	1.2	1.7	2.5	1.6	1.9
Phenylalanine	3.8	4.3	3.6	2.4	2.7	4.0	5.1	2.9
Proline	18.3	16.7	14.4	11.8	8.4	8.5	5.1	4.8
Serine	6.1	7.7	6.3	7.7	8.0	8.0	6.7	8.2
Threonine	5.0	4.3	7.1	8.9	4.9	2.5	8.0	7.2
Tyrosine	2.5	1.9	3.6	5.3	4.6	5.0	5.7	5.8
Tryptophan	0.0	0.5	0.7	0.6	1.0	1.0	2.2	1.0
Valine	8.0	9.1	7.1	6.5	4.8	5.5	6.1	6.8

Molecular weights for the camel milk caseins isolated are given in Table 3.4. They were all obtained by the electrophoretic method. The latest 5th revision of the Nomenclature (Eigel et al. 1984) recommends dropping the use of electrophoresis as a basis for casein classification and identifying caseins according to homology of their primary structure. At present, the primary structure of the individual camel is not known. Thus, the designation α, β and κ given to camel casein fractions is still uncertain and remains to be confirmed.

Pant and Chandra (1980) and Hassan et al. (1987) also reported the occurrence of proteins homologous to cow milk a-, β-casein in camel milk, but without sufficient information on the methodology applied.

Table 3.4 ***Caseins of camel milk***

Casein	**Molecular weight**	**Reference**
α_{s1}	35 000	Farah et al. (1985)
α_{s1}	31 000	Larsson-Raznikiewicz et al. (1986)
α_{s2}	25 000	Larsson-Raznikiewicz et al. (1986)
β	32 000	Farah et al. (1985)
β	27 000	Larsson-Raznikiewicz et al. (1986)

3.1.3 Size distribution of casein micelles

The size of casein micelles in camel milk was determined by electron microscopy (Farah and Rüegg 1989). Individual and pooled milk samples were cryo-fixed by rapid freezing and freeze-fractured. The total number of particles counted was 6618. The mean diameter of the sub-micelles was 15 nm. Fig. 3.3 shows a typical electron micrograph of casein particles in a freeze-fractured sample of camel milk. The average number of particles observed on such freeze-fractured surfaces is shown graphically in Fig. 3.4. The distribution is significantly broader than that of cow and human milk (Rüegg and Blanc, 1982) and shows a greater number of large particles. The particles in the lowest size class with diameters smaller than 40 nm comprise about 80 % of the total number of particles, but represent only 4-8 % of the mass or volume of the casein in camel milk. It is therefore meaningful to consider the weight or volume frequency distribution. Fig.3.5 shows the volume frequency of the pooled data of the camel milk samples compared with the distributions found in cow and mature human milk reported by Rüegg and Blanc (1982). The volume distribution curve of casein micelles in camel milk is broad and shows a maximum between 260 and 300 nm (cow milk 100-140 nm).

Figure 3.3 ***Freeze-fractured casein micelles in camel milk (cm = casein micelles; sm = sub-micelles) (Farah and Rüegg 1989)***

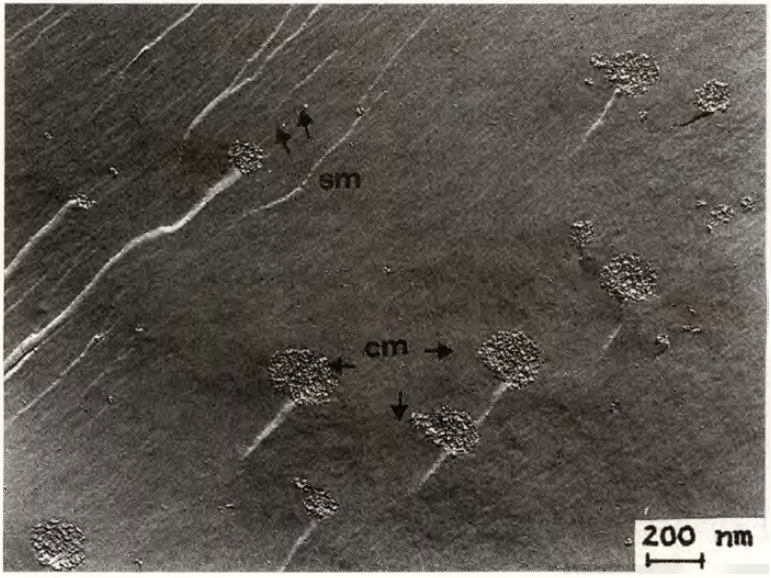


Figure 3.4 ***Number of particles observed in freeze-fractured camel, cow and human milk. (Farah and Rüegg 1989).***

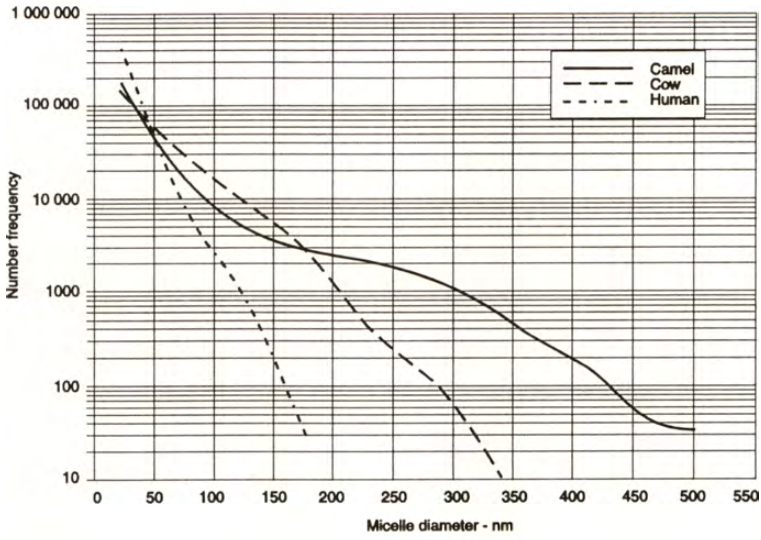
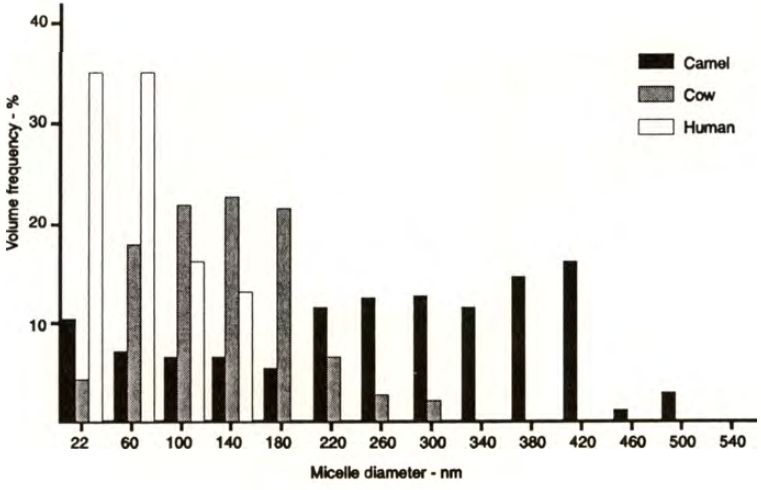


Figure 3.5 ***Size distribution of casein micelles in camel milk compared to cow and human milk (Farah and Rüegg 1989).***



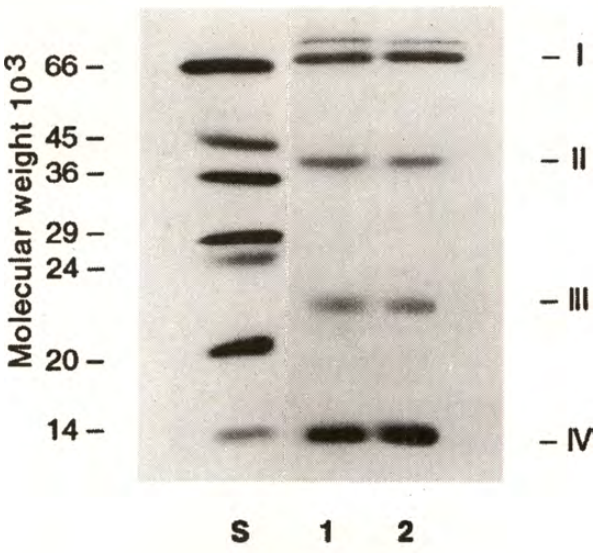
The casein micelle determines the colloidal stability of the polydisperse system milk. Reports which give a detailed picture of the native state of the casein micelles in milk other than cow milk are lacking. The state of the casein micelle structure in camel milk has rarely been investigated. Apart from our study, only two works have been published on the subject. Gouda et al. (1984) examined the casein micelles of an unspecified number of Egyptian camel milk samples. The milk was solidified with agar and examined in thin sections by electron microscopy. The casein micelles ranged in size from 25 to more than 400 nm. The technique applied did not allow clear identification of smaller micelles. Ali and Robinson (1985) determined the size distribution of casein micelles in six samples of camel milk using transmission electron microscopy. Milk was collected from individual Bedouin camels reared by nomads in Sudan. The total number of particles counted was 2448. They found that the majority of the casein micelles had the comparatively small diameter of 28-240 nm, the average being 160 nm. This value, however, overestimates the true mean because particles with diameters smaller than 14 nm could not be measured. From the few available data on camel casein micelles presented here it can be concluded that camel milk casein differs from cow milk casein in terms of micellar size distribution. Some possible consequences of this difference in relation to rennet coagulation properties of camel milk will be discussed later.

3.1.4 Whey protein fractions

On the basis of current knowledge (Eigel et al. 1984), the term „whey protein" should be used only in a general sense to describe milk proteins soluble at pH 4.6 and 20° C. The classification of the individual whey proteins should be based on the amino acid sequence in their polypeptide chains, although gel electrophoresis can still be used to identify individual whey proteins.

Relatively more work has been done on separation and characterization of camel whey proteins than caseins. Farah (1986) examined the non-casein protein fractions (NCN) of raw skim camel milk, obtained according to Aschaffenburg and Drewry (1959), by SDS-PAGE in order to be able to estimate the molecular weight (M.W.) of the individual whey proteins. The milk samples were collected from 10 individual camels on three different occasions. Both individual and pooled milk samples were used for the analysis. Fig. 3.6 gives the whey protein gel patterns of raw camel milk and shows four whey protein bands. Compared with the standard mixture of proteins in slot S, bands I and IV are identical with standard bovine serum albumin (M.W. 66 000) and α-lactalbumin (M.W. 14 000). The estimated M.W. of bands II and III were 43 000 and 23 000 respectively. These bands, however, have not yet been identified.

Figure 3.6 ***SDS-PAGE patterns of whey proteins prepared from raw camel milk 1 pooled sample; 2 individual sample; S standard marker proteins***



One of the main whey proteins is β-lactoglobulin. Proteins with the characteristics of β-lactogobulin have been isolated from bovine, ovine and caprine milk (Hambling et al. 1992). Until now no data have been published on the occurrence of β-lactoglobulin in camel milk. On the basis of the values of the M.W. the two whey proteins bands II and III cannot be homologues of β-lactoglobulin. The M.W. of β-lactoglobulin is 18 500 as monomer and 37 000 as dimer (Hambling et al. 1992).

Further studies on camel whey proteins have been reported by Conti et al. (1985) and Beg et al. (1985). Conti et al. (1985) separated camel whey proteins by gel chromatography on Sephadex G100 and identified some components by electrophoretic methods. The study revealed the presence of immunoglobulins and serum albumin; two different α-lactalbumins were also isolated and characterised. These two proteins, α-lactalbumin A and B, had similar molecular weights (around 14 000), immunological properties and electrophoretic mobility, but had different isoelectric points, amino acid composition and N-terminal sequence.

Beg et al. (1985) separated camel whey proteins by gel chromatography on Sephadex G25 and purified them by reversed-phase high performance liquid chromatography (HPLC). Amino acid and primary structure analysis revealed the presence of whey proteins homologous to bovine α-lactalbumin. The isolated camel α-lactalbumin had a M.W of 14 600 and was found to contain, like bovine α-lactalbumin, 123 amino acid residues. Mobility on SDS-PAGE was also identical for the two proteins. In other studies Beg et al. (1984, 1986 and 1987) isolated and characterised two camel whey proteins which did not show homology with known bovine whey proteins. One of the novel camel whey proteins with the M.W 14 000 is rich in cysteine/half-cystine, having 16 half-cystine residues in a total of 117 amino acid residues . Since such residues usually occur in disulphide links in proteins, the new camel whey protein is likely to have a rigid, highly cross-linked polypeptide chain. This protein exhibited some structural similarities to bovine β_{A2}-casein in the N-terminal region, the difference being, however, that this β-casein lacks cysteine-residues. The other new camel whey protein found in these studies had a M.W of 15 000 and consisted of 112 amino acid residues but no cysteine. No obvious structural similarities were noted between the novel camel milk proteins and other known milk proteins.

Camel whey proteins isolated and identified so far are presented in Table 3.5 They were isolated from raw skim milk. The casein was removed either by acidification to pH 4.6 or by high speed centrifugation. Individual whey proteins were identified according to their chromatographic and electrophoretic mobilities. Some whey proteins were classified on the basis of their amino acid sequences.

Table 3.5 ***Whey proteins of camel milk***

Protein	Molecular weight	Reference
Immunoglobulins	-	Conti et al. (1985)
Serum albumin	-	Conti et al. (1985)
Serum albumin	66 000	Farah (1986)
Serum albumin	-	Beg et al. (1987)
α-lactalbumin A	14 000	Conti et al. (1985)
α-lactalbumin B	14 000	Conti et al. (1985)
α-lactalbumin	14 000	Farah (1986)
α-lactalbumin[1)]	14 600	Beg et al. (1985)
novel camel whey protein[1)]	14 000	Beg et al. (1986)
novel camel whey protein [1)]	15 000	Beg et al. (1987)

1) primary structure determined

3.2 Lipids

Lipids in milk fat serve nutritionally as an energy source, act as a solvent for fat-soluble vitamins and supply essential fatty acids. In milks of all species studied, triglycerides are by far the major lipid class of milk fat, accounting for 97 to 98 % of the total lipids. The triglycerides, which contain a great variety of fatty acids, are accompanied by small amounts of di- and mono-acylglycerols, cholesterols, free fatty acids and phospholipids (Christie 1983).

The fat content in camel milk varies between 2.7 and 3.6 %. Most of the data available on camel milk fat are on the fatty acid composition and to a lesser extent on phospholipids and the properties of fat globules.

3.2.1 Fatty acid composition

According to the limited literature available, the first data on fatty acid composition in camel milk fat were published by Dhingra (1934) who examined the milk fat of Indian camels using older techniques

of fractional distillation. This work was followed by studies of Glass et al. (1967) who reported the fatty acid composition of milk fat from 57 species, among them camels. Further data available on the subject are the studies of Sawaya et al. (1984), Gnan and Sheriha (1986), Hagrass et al. (1987), Abu-Lehia (1989) and Farah et al. (1989). Some representative data on the main fatty acids in camel milk fat are listed in Table 3.6; all of the data were obtained by gas liquid chromatography. Data were only considered from sources showing that camels were fed all year round exclusively by grazing with no supplementary feed. Fatty acids of milk from cows living in the same conditions are also given for comparison.

Table 3.6 ***Fatty acid composition of camel milk fat***

Fatty acid	**Camel milk fat**			**Cow milk fat**
	Farah (1989) %	*Abu-Lehia (1989)* %	*Gnan (1986)* %	*Abu-Lehia (1989)* %
C4:0	0.66	-	1.0	3.5
C6:0	0.37	-	-	2.1
C8:0	0.23	0.1	0.5	1.4
C10:0	0.90	0.12	0.1	2.1
C10:1	0.19	-	-	-
C12:0	0.79	0.77	0.5	3.1
C12:1	-	-	0.1	-
C13:0	-	-	0.1	-
C14:0	12.5	10.1	10.0	10.4
C14:1	1.1	1.86	1.5	1.70
C15:0	1.3	1.62	0.5	2.44
C15:1	0.23	-	-	-
C16:0	31.5	26.6	31.5	26.60
C16:1	9.4	10.40	9.0	1.70
C17:0	0.92	1.21	0.5	1.62
C17:1	0.60	-	0.5	-
C18:0	12.5	12.2	14.0	7.86
C18:1	19.1	26.3	25.0	29.0
C18:2	3.4	2.94	3.0	3.20
C18:3	1.4	1.37	-	1.10
C20:0	1.03	0.57	0.5	0.11
C22:0	-	0.08	-	0.23
C22:1	-	0.57	-	-

The fatty acid composition of milk fat is influenced to some degree by environmental and physiological factors such as diet, stage of lactation and genetic differences. Within these limitations, the general pattern of the spectrum of fatty acids in camel milk indicates that short chain C4-C12 fatty acids are present in very small amounts in camel milk fat compared with that of cow milk and, on the other hand, the concentrations of C14:0, C16:0 and C18:0 are relatively high.

3.2.2 Phospholipids

Phospholipids are a small, but important fraction of the milk lipids and are found mainly in the milk fat globule membrane. At present, the work of Morrison (1968a, 1968b) is the only information available on phospholipids in camel milk. Phospholipids were isolated from cow, sheep, Indian buffalo, ass, pig, human and camel milks by quantitative two-dimensional thin-layer chromatography. The phospholipids of camel fat globule membrane were found to contain 35.5 % phosphatidylethanolamine, 23 % phosphatidylcholine and 28 % sphingomyelin as major components. The fatty acids of camel milk phospholipids have high amounts of C18:3 fatty acid as well as long-chain polyunsaturated acids. Its sphingomyelin contains a higher proportion of C24:1 and less C23:0 fatty acids than that of other ruminant herbivores. It was concluded that the fatty acid composition of camel milk phospholipids is not typical of ruminants since ruminants as herbivores contain predominantly branched-chain fatty acids in all of their phospholipids and only a small amount of fatty acids with more than two double bonds.

Camel and bovine milk phospholipids also differ in their plasmalogen content. Plasmalogen is phosphatidylethanolamine (PE) or phosphatidylcholine (PC) in which the C1 of the glycerol moiety is linked via an ether bond to an α, β-unsaturated alcohol. Camel milk PC contains 1 % and PE 15 % plasmalogen. The plasmalogen content of bovine PC and PE is 4 % and 1 % respectively.

3.2.3 Size and properties of fat globules

The vast majority of the fat in milk is distributed in form of small spherical globules of varying sizes. The surface of the fat globules is coated with a thin layer known as the fat globule membrane, which acts as the emulsifying agent for the fat. Until recently, the fat globule membrane of camel milk had not received any attention.

Gouda et al. (1984) reported an electron microscopy study on the size distribution of fat globules of camel milk solidified with agar and examined in thin sections . Fat globules ranged in diameter from 1 to 5 µm with nearly 50 % in the 2 to 3 µm range.

Knoess et al. (1986) analysed camel milk from five different animals and found an average size of globules between 2.31 and 3.93 µm. They also observed that the fat globule membrane in camel milk was far thicker than in milk of other species, the term „thickness" being used in relation to the diameter of the fat globule. In a study on some physical properties of camel milk, Wahba et al. (1988) found that the size of the fat globules in camel milk varied between 2.60 and 3.25 µm with an average of 2.9 µm. In natural creaming, the fat globules rise under the action of gravity as milk fat has a lower density than milk plasma. The fat globules do not rise separately but rather in floccules comprising many globules; the floccules are formed by agglutination (Mulder and Walstra 1974).

Natural creaming is no longer of practical significance to dairy industry, as fat is normally recovered by centrifugal separation. Nevertheless, knowledge of the creaming process still has scientific importance to understand the properties of fat globules, such as clustering, that are significant in the behaviour of milk and some of its products (Walstra 1983). During field experiments in Kenya (Farah and Streiff 1987) it was observed that, upon standing, camel milk creams by gravity less rapidly and completely than cow milk. For proper understanding of this behaviour, the creaming ability and the size distribution of fat globules in camel milk were investigated (Farah and Rüegg 1991).

For natural creaming, raw and heated camel milk samples were examined and compared with cow milk. The milk samples were heated for 30 minutes at 55, 60, 62, 68, 70 and 77° C, left to cream off at 4° C and the cream layer was measured after 5 and 24 hours. Compared with cow milk, camel milk shows a very slow creaming rate at all temperatures. Creaming layers varied from 0.5 to 2 ml at 4° C. Creaming of camel milk samples at room temperature was not significantly different from that creamed at 4° C. Extending the creaming time up to 48 hours did not produce any significant increase in the creaming layer.

It is well established that the main factor responsible for rapid formation of the cream layer on cow milk is a protein absorbed on fat globules, which has the characteristics of a euglobulin. This pro-

tein, known as fat agglutinin, promotes clustering of globules (Mulder and Walstra 1974). To determine whether the low creaming capacity of camel milk could be due to a deficiency in agglutinin, creaming ability was studied in various combinations of skim milk and cream of raw camel and cow milk. The volume of cream and fat content obtained after creaming for 24 hours are presented in Table 3.7. All systems containing camel skim milk creamed poorly. Mixing a cream with its own skim milk yielded a cream layer approximately equal to that of the original unseparated milk. The milk from camel cream and cow skim milk creamed much better than camel milk and the mixture of cow cream and camel skim milk. This could be an indication that camel milk lacks the agglutinating substance required to cluster fat globules. The creaming behaviour of camel milk appears to be similar to that of buffalo and goat milk, which also show poor creaming ability due to an insufficient quantity of agglutinin (Abo-Elnaga et al. 1966; Parkash 1968).

Table 3.7 ***Creaming of camel and cow milks and of various combinations of cream and skim milk (Farah and Rüegg 1991)***

Sample	Cream layer[1)] after 24 h - ml	Fat in lower 50 ml of cylinders after 24 h - %
Cow milk	12	0.8
Camel milk	1	3.2
Cow skim + cow cream	11	0.7
Camel skim + camel cream	1	3.4
Cow skim + camel cream	7	2.0
Camel skim + cow cream	3	2.9

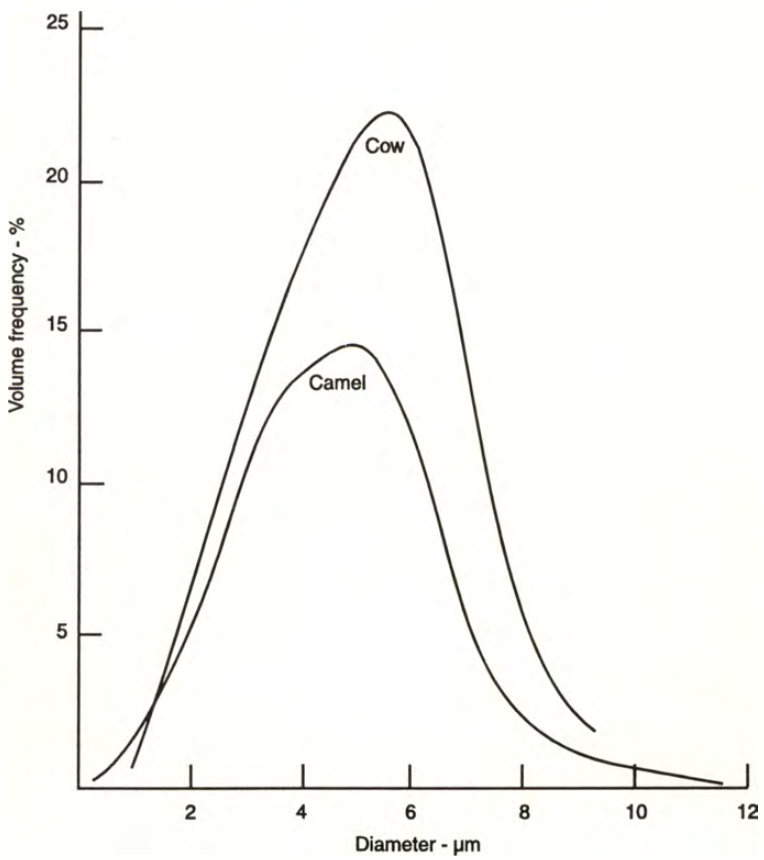
1) in 100 ml measuring cylinder, storage at 4° C

To examine whether the observed difference in creaming power between camel and cow milk could be related to differences in the size of the fat globules, the size distribution of camel milk fat was determined by light microscopy (Farah and Rüegg 1991). A total of 1800 particles were counted. Fig. 3.7 shows the frequency distribution of fat globules in camel milk compared with the distribution found in cow milk (Precht et al. 1987). The results show similar globule size distribution in cow and camel milks. From the light microscopy data a number average diameter of 2.61 μm could be calculated. Therefore, the difference observed in the creaming be-

haviour between cow and camel milk cannot be explained by differences in the size of fat globules. No data have been reported on the creaming process of camel milk and very few references on the size of camel milk fat globules are cited in the literature.

The results of the investigation indicate that an insufficient quantity of agglutinin in camel milk may be responsible for the slow creaming rate. However, it is also possible that camel milk contains the protein required to cluster fat globules but that structural features of the protein are such as to preclude adsorption to the fat globules. Other factors, such as electrical charges on the globules, ionic distribution, and interfacial tension between milk sera and fat globules may also contribute to the poor creaming ability of camel milk.

Fig. 3.7 ***Size distribution of fat globules in camel and cow milk (Precht et al., 1987; Farah and Rüegg, 1991)***



3.3 Lactose

Lactose is the major carbohydrate in the milk of all mammals and it is generally accepted that there are no non-mammalian sources of lactose.

The lactose content in camel milk ranges from 3.4 to 5.6 % and is slightly higher than the lactose content in cow milk. Hassan et al. (1987) determined the lactose content in camel milk during the lactation period and found minimal variation. Examining the effect of drought on the composition of camel milk, Yagil and Etzion (1980) found that lactose content was low at birth, being around 2.8 %, but within 24 hours it increased to 3.8 %. There was a further increase up to 5 % as long as drinking water was available. Dehydration of the animals led to a decline in milk lactose content to as low as 2.9 %. According to the authors this change in lactose concentration would account for the milk being described sometimes as sweet and other times as bitter.

3.4 Salts and vitamins

Milk mineral salts are mainly chloride, phosphates and citrates with sodium, calcium and magnesium. Although salts comprise less than 1 % of the milk, they influence the physical state and stability of milk proteins, particularly the phospho-caseinate-complex. The mineral content of camel milk expressed as ash ranges from 0.6 to 0.8 %. Little information is available on the detailed composition of camel milk minerals, and this is summarised in Table 3.8. These studies appear to be the only ones in which all of these constituents were determined in the same sample. Although salt composition of milk is influenced by factors such as health status of the udder and stage of lactation, the major salt constituents of camel milk seem to be similar to those of cow milk. The few available data on chloride and citrate content in camel milk (Yagil and Etzion 1980; Hassan et al. 1987; Farah and Rüegg 1989) also show similarities to those of cow milk.

Table 3.8 ***Mineral content of camel milk***

Na mg/100ml	**K** mg/100ml	**Ca** mg/100ml	**Mg** mg/100ml	**P** mg/100ml	**Reference**
59	173	115	14	84	Abu-Lehia (1987)
36	60	132	16	58	Gnan and Sheriha (1986)
36	62	116	8	71	Hassan et al. (1987)
69	156	106	12	63	Mehaia and Al-Kahnal (1989)
-	-	157	8	104	Farah and Rüegg (1989)
35-60	135-155	100-140	10-15	75-110	Cow milk

Only fragmentary information is available on vitamin content in camel milk. Data in Table 3.9 are the only ones from studies in which several vitamins were determined in the same sample. The results show that, compared with cow milk, camel milk contains less vitamin A, B_1, B_2, E, folic acid and pantothenic acid, while the content of vitamin B_6 and B_{12} is at about the same level. The content of niacin and vitamin C is substantially higher than that of cow milk. In particular the high level of vitamin C in camel milk has been confirmed by several studies (Kon 1959; Knoess 1979; Mehaia and Al-Kahnal 1989; Farah et al. 1992). The relatively fair amount of vitamin C (range reported in the literature 25 to 60 mg/l) in camel milk is of significance from the nutritional standpoint since in arid areas fruit and vegetables containing vitamin C are scarce.

Table 3.9 ***Vitamin content of camel and cow milk***

Vitamin	Camel milk			Cow milk
	Sawaya (1984) mg/kg	Knoess (1977) mg/kg	Farah (1992) mg/kg	Ciba-Geigy (1977) mg/kg
A	0.15	-	0.10	0.17-0.38
B1	0.33	0.60	-	0.28-0.90
B2	0.42	0.80	0.54	1.2-2.0
B6	0.52	-	-	0.40-0.63
B12	0.002	-	-	0.002-0.007
E	-	-	0.53	0.2-1.0
Niacin	4.6	-	-	0.5-0.8
Folic acid	0.004	-	-	0.01-0.10
Pantothenic acid	0.88	-	-	2.6-4.9
C	24	23	36	3-23

4 Enzymatic coagulation of milk

Coagulation of casein micelles in milk can be achieved by various proteolytic enzymes obtained from animal, plant and microbial sources. Enzymes traditionally used in the manufacture of cheese are chymosin and pepsin, the former being extracted from calf stomach and the later from cow stomach.

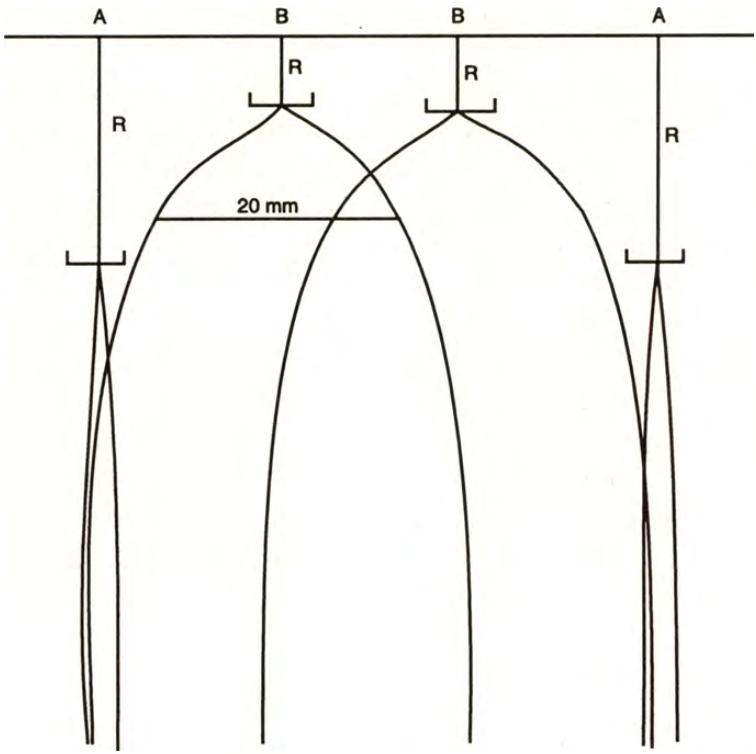
In the coagulum formation process, three phases can be distinguished (Dalgleish 1992). In the primary phase, the κ-casein of the casein micelles is hydrolysed by the protease to yield two peptides of different properties, a hydrophilic macropeptide which is split off from the micelle and the hydrophobic para-κ-casein which remains in the micelle. The progressive hydrolysis of κ-casein during the primary phase leads to the alteration of the properties of the casein micelles, resulting in aggregation in the presence of Ca^{++} as the secondary phase of the rennet coagulation. In a third phase of the process, the firmness of the gel increases due to syneresis.

There is very little information available on the enzymatic coagulation of camel milk, and in addition, the few available data are often contradictory. Some authors have reported that camel milk cannot be coagulated with rennet unless it is mixed with milk of other species such as goats, ewes or buffaloes (Rao et al. 1970; Yagil 1982). Others reported that camel milk can be coagulated by itself, but a very high dosage of calf rennet is necessary to reach detectable coagulation (Gast et al. 1969; Chapman 1985). The most detailed studies available, although still far from being complete, are those of Farah and Bachmann (1987), Ramet (1987), Mehaia et al. (1988) and Mohammed and Larsson-Raznikiewicz (1989).

Farah and Bachmann (1987) examined the rennet coagulation of 10 individual camel milk samples from Northern Kenya using commercial calf rennet powder. The concentration of the rennet solution was such to give a visually observed coagulation time of about 5 minutes with cow milk as a reference. The coagulation time of camel and cow milk was measured in a Formagraph according to the procedure of McMahon and Brown (1982). Typical Formagraph

recordings of duplicate cow and camel milk samples are shown in Fig. 4.1. The coagulation time (R) is determined by measuring the distance from the origin to the point where the baseline begins to increase in width. With the same amount of rennet, the coagulation time (R) of camel milk was two to three times longer than that of cow milk. The curd firmness is determined by measuring the time from the start of gel development until a width of 20 mm is reached and is expressed as K_{20}. Following this definition, curd firmness could not be measured in camel milk as this width was never reached, owing to the failure of curd formation.

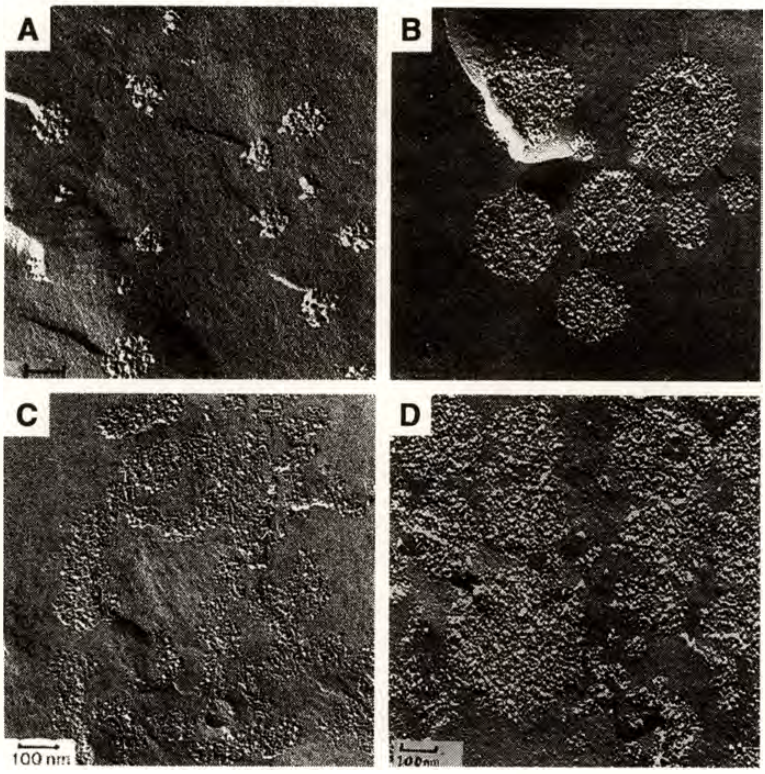
Fig. 4.1 ***Formagram of duplicate camel (A) and cow (B) milk samples adjusted to pH 6.65; R = coagulation time (Farah and Bachmann 1987)***



The coagulation process of camel and cow milk was also studied by electron microscopy (Farah and Bachmann, 1987). Milk samples were taken before and after addition of rennet at time intervals up to the visually observed coagulation. The samples were freeze-fractured according to the procedure of Müller et al. (1980). Electron micrographs of the casein micelles of camel and cow milk are presented in Fig. 4.2. Both cow (A) and camel casein (B) micelles appeared as almost spherically shaped particles composed of numbers of submicelles. Cow casein micelles are dispersed over the field whereas camel casein micelles are more aggregated and grouped together. In all the examined fields the size of the camel casein particles appears greater. In the cow milk, onset of the aggregation, as observed in electron micrographs, began at approximately 60 to 80 % of the visible coagulation time. Many casein micelles were already linked together marking the beginning of a network formation. At the coagulation time (C) a network of casein micelles could be observed. In camel milk, the electron microscopic observation showed very poor micellar aggregation at the coagulation time (D). In contrast to cow milk, where at coagulation point a network of mostly fused micelles is formed, camel casein micelles appear to form a less compact and looser network linked merely by contact with very little visible change in the original micellar structure.

The effects of temperature, pH and calcium chloride on coagulation time were also studied by Farah and Bachmann (1987). As observed with cow milk, the coagulation time of camel milk was reduced with decreasing pH, with increasing temperature and added calcium. This allows the conclusion to be drawn that the response to the changes in pH, temperature and calcium concentration in camel milk is similar to that of cow milk, but the difference in the coagulation time still remains. The rate of liberation of non-protein nitrogen (NPN) from casein by the action of rennet was measured by monitoring the increase of N-compounds soluble in 12 % trichloroacetic acid. In both camel and cow milk, the amount of NPN released by the action of rennet increased at first, and reached a maximum at the coagulation point, after which it declined constantly at a slow rate. The increase of NPN as a percentage of total casein-N was higher in cow milk (2 %) than in camel milk (1,8 %).

Fig. 4.2 ***Electron micrographs (x75 000) of freeze-fractured casein micelles in camel and cow milk before and after rennet coagulation.***
A,C = Cow milk before and after coagulation
B,D = Camel milk before and after coagulation
(Farah and Bachmann 1987)



Ramet (1987) studied the rennet coagulation of pooled Saudi camel milk samples with calf rennet powder. The rennet concentration was adjusted to obtain an average clotting time of 13 minutes. The main emphasis in the investigation was to study the effect of calcium on the clotting of camel milk in comparison with cow milk. To coagulate camel milk as quickly as cow milk, four times as much rennet had to be added. A progressive reduction in clotting time occurred up to 1.5 mM calcium addition, after which no further reduction of clotting time was observed. The influence of calcium was more pronounced in cow milk than in camel milk. The authors recommended that the amount of calcium salt added be limited to 15 g/100 l (1-2 mM). This amount of salt reduces the coagulation time of camel milk up to 50 % without significantly increasing the bitterness of the cheese.

Immobilised chymosin or pepsin is usually used in experiments to separate the primary from the secondary phase of the coagulation process. For the primary reaction, the milk at 15° C or below is passed through a column of immobilised enzyme. The temperature of the effluent milk from the column with its k-casein hydrolysed to para-k-casein and casein macropeptide (CMP) is then increased to 30 to 35° C to start the secondary phase leading to coagulation and curd formation (Dalgleish 1982). Applying this technique, Mehaia et al. (1988) studied the effects of temperature, pH and calcium concentration on the primary and secondary phases of camel milk coagulation using soluble and immobilised chymosin. With both forms of the chymosin the coagulation time of camel milk decreased with decreasing pH, increasing temperature and added calcium. The authors report that the clotting times were reduced more with soluble than with immobilised chymosin. However, according to the data presented no significant differences could be found.

Mohammed and Larsson-Raznikiewicz (1989) studied the coagulation properties of Somali camel milk using bovine chymosin. With the same chymosin concentration, the coagulation time for camel milk was 2 to 3 times longer than that for cow milk. With increasing chymosin concentration, the clotting time decreased in both milks. However, the difference in coagulation time between camel and cow milk still remained.

From all these studies it can be concluded that camel milk casein is accessible to chymosin. The action of rennet on camel milk leads to coagulation in the form of flocs with no firm coagulum. The reason for this behaviour is still not known, but the following hypotheses can be considered.

The primary phase of the enzymatic coagulation in bovine milk is the hydrolysis of the peptide bond between residues 105 (phenylalanine) and 106 (methionine) of κ-casein resulting in the formation of para-κ-casein and glycomacropeptide. The hydrolysis rate can be determined by measuring either the 12 % trichloracetic acid (TCA)-soluble glycomacropeptide as NPN or the detection of para-κ-casein by electrophoresis. A primary phase reaction similar to that of bovine milk seems to occur between chymosin and camel milk casein. A fragment soluble in 12 % TCA could be measured during rennet action as NPN in camel milk (Farah and Bachmann 1987, Mehaia 1987). Additional electrophoresis of chymosin-treated camel casein showed a protein band not seen in untreated casein

(para-κ-casein) but its origin could not be detected on the electrophoretic pattern (Farah, unpublished observation). The liberation of NPN and the changes in the electrophoretic pattern of chymosin-treated camel casein are indications of a primary phase reaction in camel milk.

In bovine milk, the hydrolysis of κ-casein during the primary phase leads to aggregation of casein micelles and formation of coagulum. In camel milk, however, the hydrolysis leads to formation of a soft coagulum in the form of flocs and no firm curd can be obtained. The reason for the failure of camel milk to form coagulum with chymosin is still not known at present. However, electron microscopy studies of camel and cow milk at different times after the addition of rennet showed different courses of casein micelle aggregation. As shown in Fig. 4.2, in camel milk no micellar aggregation similar to that of cow milk could be observed by electron microscopy. Examining the extent of chymosin action on milk samples and then studying their aggregation, Dalgleish (1979) and Green (1981) found that until some 80 % of the κ-casein has been hydrolysed, the rate of aggregation is negligible. Above 80 % proteolysis, the aggregating potential of the micelles increases, reaching a maximum when all the κ-casein has been hydrolysed. According to these studies there appears to be a critical value for κ-casein hydrolysis below which casein micelles can not aggregate. Presumably, the failure of camel casein to form coagulum is due to insufficient hydrolysis of κ-casein. The amount of κ-casein cleaved by the enzyme is not enough for effective aggregation. The failure of coagulum formation could also be due to non-specific interaction of the protease and κ-casein. Thus, it can be assumed that chymosin attacks camel κ-casein at residues other than the region of the 105/106 peptide bond, leading to non-specific proteolysis and formation of weak coagulum.

Up to the present, calf rennet has been used for clotting camel milk. However, there are some reports in the literature that a clotting enzyme from a particular species is more effective with milk of the same species. Rennet extracts from lamb where found to be more effective with ewe's milk than with cow milk (Herian and Krcal 1971). Pig chymosin and pig pepsin showed higher clotting activity with porcine milk than with bovine milk (Foltmann et al. 1981). These results suggest an adaptation of the enzyme specificity of the gastric proteinases and the structure of the caseins. Therefore, camel rennet could be more effective in camel milk than calf rennet.

To look at the action of camel rennet on camel milk, Wangoh, Farah and Puhan (1993) extracted bovine and camel rennet from abomasa of young calves. The clotting activity was determined during extraction and activation. Both camel and bovine abomasal extracts were fractionated and the clotting activities of the fractions compared. Camel rennet coagulated camel milk slightly faster than cow milk, while cow rennet extract coagulated camel milk less readily than cow milk. The chymosin fraction of bovine calf rennet showed weak activity on camel milk while the pepsin fraction coagulated camel milk much more readily than cow milk. The chymosin fraction of camel rennet coagulated cow and camel milk equally well, whereas the pepsin fraction showed higher clotting activity with camel milk. It was concluded that the coagulation of camel milk by bovine rennet is primarily due to its pepsin content. The reported large variations in the ability of bovine rennet in coagulation camel milk can be explained by the differing pepsin content of the rennet used. Camel milk should, therefore, be coagulated with camel rennet or bovine pepsin.

As shown with cow milk, both the dimension and the composition of the casein micelles are of great importance for the coagulation process. Coagulation time varies with the micelle size, and reaches an optimum with small and medium size micelles which have higher κ-casein contents than the larger micelles (Ribadeau-Dumas and Garnier 1969 and Ekstrand et al. 1980). Smaller micelles also give firmer curd than larger micelles at the same casein concentration (Grandison 1986). As pointed out in section 3.1.3, the size distribution of casein micelles in camel milk is significantly broader than that of cow milk, with a greater number of larger micelles of 350 to 500 nm. The poor rennetability could be related to this difference in the size of casein particles.

The concentration of specific ions, especially calcium ions, has an effect on the rate of coagulation and it is well known that an addition of calcium ions to milk reduces the coagulation time. This effect, however, is due not only to the increase in calcium ions concentration but also to the reduction of milk pH. Data on overall content of Ca and other minerals in camel milk are very limited. However, available information indicates no difference between cow and camel milk in mineral content (Gnan and Sheriha 1986, Hassan et al. 1987, Abu-Lehia 1987, Mehaia et al. 1988). On the other hand, the equilibrium between free and colloidal calcium in milk affects rennetability and curd firmness. Information on salt equilibrium in

camel milk is also very limited. The only study reported in the literature is the work of Farah and Rüegg (1989). In this study the distribution of calcium, magnesium, phosphorus and citrate between the dissolved and colloidal phases in camel milk was examined using ultrafiltration. In 10 individual camel milk samples the distribution was very similar to that of cow milk with the exception of the concentration of citrate which was lower in camel milk.

Coagulum strength is also related to the total casein concentration in milk. As shown in Table 3.1, total casein content in camel milk varies between 1.9 and 2.3 %, and is lower than that of cow milk (2.4-2.8 %). Although the present data on camel milk composition are by no means systematic or extensive, the reduced firmness of camel milk coagulum can be partly related to the low total casein concentration.

An important factor which also has to be considered is the effect of genetic polymorphism of caseins on the coagulation properties of milk. For obvious economic reasons, most of the research in this area has been concentrated on bovine and to a lesser extent on the caprine species (Ng-Kwai-Hang and Grosclaude, 1992). However, the genetic polymorphism of camel milk proteins is not known, and cannot be considered. The information presented here does not permit any conclusive explanation for different coagulability between camel and cow milk. Further comprehensive studies on camel milk components, particularly on casein components and their interaction, are needed to understand the coagulation properties of camel milk.

5 Effects of heat on milk

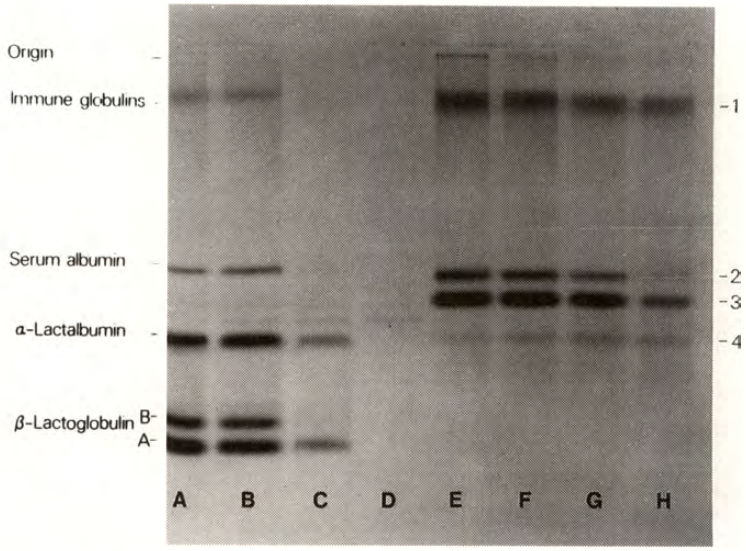
The effects of pasteurisation and sterilisation have been extensively studied with cow milk because of their importance in understanding the changes in the properties of milk induced by denaturation of whey protein (Singh and Creamer 1992). Most of these studies are, however, limited to cow milk due to its widespread industrial processing and commercialisation. Heat processing as a means of preserving milk is not yet applied to camel milk and up to now, only Farah (1986) has studied the effect of heat treatment on whey proteins of camel milk. The milk was heated to 63, 80 and 90 °C for 30 min and the amount of undenatured whey proteins determined using the Aschaffenburg and Drewry (1959) method. The whey proteins were also examined by PAGE. Table 5.1 shows the extent of denaturation of the whey proteins in heat treated milk relative to the control raw milk.

Table 5.1 ***Heat denaturation of whey protein of camel and cow milk (Farah 1986)***

Batch	Temperature	Undenat. WPN		Denat. WPN	
	Holding time 30 min °C	Cow mg/100 g	Camel mg/100 g	Cow % of WPN	Camel % of WPN
1	Raw	88	77	0	0
	63	82	65	7	16
	80	22	50	75	35
	90	17	41	81	47
2	Raw	97	93	0	0
	63	90	81	7	13
	80	26	63	73	32
	90	18	49	81	53
3	Raw	91	100	0	0
	63	81	85	7	15
	80	26	67	70	33
	90	23	49	74	51

Camel milk whey proteins generally showed higher heat stability than those from cow milk. The degree of denaturation of the whey proteins varied in camel milk from 32 to 35 % at 80° C and 47 to 53 % at 90° C. The higher heat stability of camel whey proteins, compared with cow milk whey proteins, could also be confirmed by means of PAGE as shown in Fig. 5.1.

Fig. 5.1 ***Polyacrylamide gel patterns of whey protein filtrates prepared from camel and cow milk heated for 30 min at various temperatures. Cow milk: A, raw; B, 63°C; C, 80°C; D, 90°C. Camel milk: E, raw; F, 63°C; G, 80°C; H, 90(Farah 1986)***



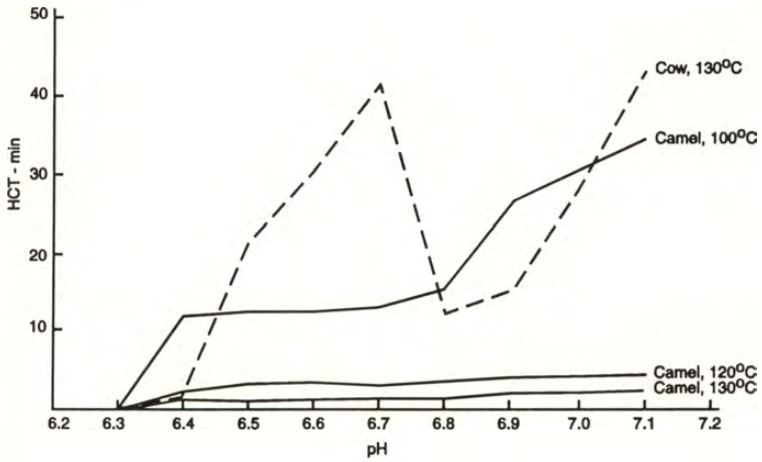
The main protein bands of camel milk are designated by the numbers 1, 2, 3 and 4. The electrophoretic patterns in slots E, F and G show one faint band in the upper regions of the gel (component 1) followed by two sharp bands and one faint band in the lower part of the gel (components 2, 3 and 4). The whey protein bands show a pronounced heat effect only in the 90° C sample (slot H), where band intensities decrease without totally disappearing.

As a comparison, pasteurisation of cow milk at 63° C, 30 min caused no visible change in whey proteins (slot B), while at 80° C, 30 min (slot C) immunoglobulins and serum albumin disappeared. Portions of β-lactoglobulins A and B and a-lactalbumin remain undenatured at 80° C, but disappeared after heat treatment of 90° C for 30 min (slot D).

In order to study the ability of camel milk to withstand high processing temperatures, the heat coagulation time (HCT) was studied (Farah and Atkins 1992). The heat stability of milk is defined in terms of the time required to induce coagulation at a given temperature. For bovine milk, the most widely used temperature for heat coagulation is 130 or 140° C. Preliminary experiments showed that in camel milk the HCT of < 1 min observed at 140° C was too short for the

assay. HCT was, therefore, determined at 100, 120 and 130° C according to the method of Davies and White (1966). Milk was adjusted to various pHs in the range 6.5 to 7.1; the original pH was 6.50 for camel and 6.65 for cow milk. Fig. 5.2 shows the HCT/pH curves for pooled camel and cow milk. The shape of the heat coagulation time/pH curve for camel milk at the lowest temperature was different from those at high temperatures. The milks heated at 130 and 120° C were very unstable at all pH-values and coagulated in 2 to 3 min.

Fig. 5.2 ***Heat coagulation time/pH curves for camel and cow milk. (Farah and Atkins 1992)***



At 100° C the heat coagulation time initially increased up to pH 6.4 and remained constant between pH 6.4 and 6.7. The heat coagulation time at this pH-interval was around 12 min and increased progressively with increasing pH.

The HCT/pH curve in cow milk is in agreement with findings reported in the literature and shows a maximum around pH 6.7 and a minimum near pH 6.8. The heat stability increases above 6.8. This type of curve of pronounced stability maximum and minimum is designated type A. Most cow milk shows type A-behaviour, but there are some milks (type B) which give a curve with no maximum or minimum (Rose 1963; Singh and Creamer 1992).

The heat stability of milks other than bovine milk has received little attention. However, considerable inter-species differences in the shape of HCT/pH curves have been reported. Fox and Hoynes (1976) examined the heat stability of ovine and caprine milks. The original pHs of the milks were 6.7 for caprine and ovine milk. The pHs were adjusted to values over the range 6.4 to 8.0 and heat stability was determined at 120, 130 and 140° C. Ovine and caprine milks showed a stability maximum at pH 7.0 in their HCT/pH curves and were very unstable at all higher pH-values. From the study of Farah and Atkins (1992) and the work of Fox and Hoynes (1976) it can be concluded that the shape of the HCT/pH curves changes according to the origin of the milk. The HCT/pH curve of bovine milk shows a pronounced maximum and minimum, ovine and caprine milk have a maximum but no minimum, whereas the HCT/pH curves of camel milk showed no maximum and no minimum heat stability. Within the four species camel milk has the lowest heat stability. The reason for this poor heat stability of camel milk is not yet known; nevertheless, it can be discussed on the basis of current knowledge of the heat coagulation of bovine milk. Factors which influence the heat stability of bovine milk have been the subject of intensive research over a long period and are reviewed by Singh and Creamer (1992). In general there are a number of inter-related factors which influence the heat stability of bovine milk. This includes compositional factors such as pH, concentration of salts and concentration of proteins.

It can be concluded from the above mentioned review that the influence of pH becomes evident when the pH of cow milk is artificially adjusted. In the range 6.5 to 7.0 there is a marked maximum in the HCT/pH curve at pH 6.7 and a minimum at pH 6.9. The original pH of the milk can be above, below or at the pH of maximum stability so that heat stabilization of the milk can be attained by adjusting the pH to ≈6.7. This pH dependence of the heat stability of milk is effected by the milk proteins, in particular β-lactoglobulin and κ-casein, which form a complex during heating.

Hindering complex formation in heated milk by addition of sulphydryl blocking agents reduces the maximum in the HCT/pH curve, showing that the interaction between heat denatured β-lactoglobulin and κ-casein via disulphide bonds is responsible for the influence of pH on the sensitivity of milk to heat treatment. On the other hand, the minimum in the HCT/pH curve of type A milk is reduced or completely eliminated on enrichment of the milk with κ-casein. Further-

more, type B milk can be converted to type A-milk by removing κ-casein or by increasing the level of soluble κ-lactogobulin. This suggests that the heat stability patterns of milk are controlled by the proportion of κ-casein and β-lactogobulin. In addition, soluble salts, especially calcium and phosphate, are also thought to play an important role in the heat stability of milk.

All these investigations have concentrated on bovine milk and no comparable studies are available for camel milk. The only component of camel milk which can so far be related to its poor heat stability is κ-casein. Up to now no protein homologous to bovine κ-casein has been isolated from camel milk.

Although camel casein is accessible to chymosin (see section 4), limited availability of κ-casein in camel milk could be a possible explanation of the poor heat stability of this milk. The impact of other little-known factors in camel milk such as the level of soluble calcium and phosphate, as well as the concentration of colloidal calcium phosphate and the nature of its binding to casein, might also be considered. Furthermore, principal factors influencing the heat stability of milk which are unknown in camel milk are the forces which contribute to the integrity of casein micelles such as hydrophilic bonding, electrostatic interaction and disulphide bonding.

6 Camel milk products

Many pastoralists keep mixed herds with varying milking capacity to ensure a continuous supply of milk throughout the year. Others, however, mainly depend on the milk supply provided by their camels in an environment where other species would not survive or not give sufficient milk. Camel milk is therefore a very important element in the diet of most camel herders.

In the traditional pastoral communities, camel milk is consumed fresh or fermented. The milk is mainly home-consumed but also sold in the immediate vicinity of the herd. Seasonal variations in camel milk production are great and in areas where large camel herds are kept, much of the surplus milk is wasted during the rainy season by discharging it. The manufacture of butter, ghee and cheese from camel milk is still not well developed and accepted.

6.1 Fermented milk

In all animal-rearing societies, milk is traditionally consumed predominantly in the form of fermented milk. Fermentation is the only means of preserving milk under warm conditions. As fermented milk can in principle be made from every type of milk, it is often unclear from the literature whether camel milk is being used or in a mixture with other milk for producing fermented milk. Therefore, very few reports describe fermented products made exclusively from camel milk.

Rao et al. (1970) described a method for commercial manufacture of kefir from camel milk in the former USSR. Milk is flash-pasteurised at 85° C, cooled to 26 to 30° C and inoculated with 3 to 6 % of a kefir culture. During incubation for 8 to 12 hours at 20 to 26° C, a soft coagulum develops, having an acidity of 60 to 70° Th (24-28° SH). The product is further ripened for 24 to 28 hours. Martinenko et al. (1977) reported on „Chal", a traditional fermented camel milk in Kazakhstan and Turkmenistan. Raw camel milk as such, or diluted with warm water (1:1), is inoculated with previously fermented milk and incubated at 25-30° C. The milk coagulates in 3-4 hrs but is held at the same temperature for 8 hrs in order to obtain the typical taste. It is suspected that lactose-fermenting yeasts participate in the process of fermentation and ripening of Chal in addition to lactic acid bacteria. Karim and Taghdissian (1990) described „Chal" made from camel milk in Iran from heated milk subjected to both lactic acid and alcoholic fermentation.

Al-Ruqaie et al. (1987) mentioned „Oggtt", a dried fermented camel milk, made and marketed in Saudi Arabia. The milk is fermented spontaneously for 1-2 days and is then churned. The resulting buttermilk is boiled while stirring until it becomes thick. The paste is allowed to cool to about 30-35° C and then shaped by hand into small cakes, which are pressed and sun-dried. The yellowish-white final product consists of irregularly shaped small pieces and is consumed either dry or after reconstitution with water.

To prepare „Susa", which is the traditional fermented camel milk in East Africa, the milk is left to stand for 1 or 2 days until it becomes sour. Owing to the spontaneous fermentation, this traditional method results in a product with varying taste and flavour, and is often of poor hygienic quality. In a study caried out in North Eastern Kenya, Farah et al. (1990) examined the possibility of improving the traditional „Susa" using mesophilic starter cultures. The milk was heated to 85° C for 30 min, cooled to ambient temperature, inoculated with 2 to 3 % culture and incubated at ambient temperature of 27 to 30° C for 24 hrs. Two multiple mesophilic starter cultures were used: a homofermentative *O-CH:143* and a heterofermentative *B-CH:40*. Consumer acceptance ratings of the two fermented milks were compared with the traditional „Susa" from the local market. The results of the sensory evaluation and chemical analyses are presented in Table 6.1. Two groups of people were selected for the sensory evaluation, group A consisting of 13 nomads with no formal education, and group B consisting of 12 students and government officers. Both groups claimed to consume „Susa" regularly. As the panellists had no previous experience of testing products, the rating test was simplified and limited with respect to consumer preference. Each person was asked to taste the three coded samples and score each products for preference on a three point scale ranging from „most preferred „(preference score = 1) to „least preferred" (preference score = 3).

Table 6.1 ***Sensory evaluation and chemical analyses of three fermented camel milk samples (Farah, Streiff and Bachmann, 1990)***

	Mesophilic lactic culture		Traditional fermented Susa
	O-CH:143[1)]	B-CH:40[2)]	
Group A: 13 people			
mean score	2.08	1.39	2.31
Standard dev.	0.76	0.77	0.86
Group B: 12 people			
Mean score	1.58	1.50	2.92
Standard dev.	0.76	0.52	0.29
Chemical analyses:			
Total solids, %	12.7	12.7	12.5
Fat content , %	4.1	4.0	4.0
Acidity, °SH	36.2	40.0	40.0

1) Streptococcus lactis, Str. cremoris; no gas formation; no diacetyl
2) Streptococcus lactis, Str. cremoris; Leuconostoc atrovorum; diacetyl

Compared with fermented cow milk, the consistency of fermented camel milk is thin. During fermentation a flocculent precipitate is formed rather than a coagulum. As shown in Table 6.1, the values of total solids and fat content were the same in all samples. The homofermentative culture *O-CH:143* gave less-acid products, while milk fermented with the heterofermentative culture was clearly preferred by both groups. Both groups described the two cultured milks as particularly good „Susa" with uniform fresh taste although the product fermented with *O-CH:143* was less preferred.

The study shows that traditional „Susa" can be improved by using a selected mesophilic lactic acid culture. These cultures offer advantages in warm countries as it can be incubated at ambient temperature (20-30° C).

Seasonal variations in camel milk production are great. In the rainy season there is overproduction and the milk cannot all be consumed and because of the limited scale of production the traditional „Susa" can be sold only in the immediate vicinity of the herd. The method described for production of fermented milk can in particular be introduced in countries where there are large camel populations. It

allows small producers to process surplus milk on-farm or in centralized small-scale units.

6.2 Butter

Among many camel rearing societies there is a common belief that butter cannot be made from camel milk. This belief has been supported by some authors (Dickson 1951), whereas others (Yagil 1982; Knoess et al. 1986) have reported butter made from camel milk.

In a survey on processing of camel milk in North Eastern Kenya, nomads used a method for obtaining very small amounts of fat from camel milk (Farah and Streiff 1987). Several stones are heated on a fire and placed into a container filled with raw camel milk. As a result, fat droplets form and appear on the surface. The milk is then slowly cooled and beaten with a whisk until the fat droplets form small clumps of butter. The amount of butter so obtained is very small and is used medicinally or as a hair pomade.

According to Yagil (1982), in the Sahara butter is made by placing camel milk into a goat-skin for 12 hours at ambient temperature to ferment. Afterwards, air is blown into the container and the top is tied off. It is hung on a tent pole and rapidly swung to and fro. The amount of butter obtained is determined by the skill of the person doing the churning. Some cold water is added to the container before the end of churning; this helps the butter to solidify. The amount of butter obtained by this process is also very small and is used as a base for medicines or for cooking. Similar methods are also reported to be applied traditionally by bedouins in the Sinai peninsula (Yagil 1982).

More efficient methods of obtaining camel butter from cream have also been described. Purchase (1943) investigated in Kenya the possibility of making camel milk butter. Milk was separated at a temperature of 27 to 29° C. Cream was kept for 43 hours in a room with a temperature between 28 and 32° C. The sour cream was then churned at 28° C for 10 to 30 minutes and the butter granules were washed with water at ambient temperature. The butter fat yield was 60 % calculated on the basis of milk fat. Khan-Sial (1950) carried out detailed research on butter- and ghee-making by various methods. The best results were obtained when milk was warmed to 32° C, the cream washed with water at 37° C and the cream then churned. The highest recovery of butter fat (71 %), calculated on the basis of total milk fat, was obtained by churning at 21 to 24° C

for 30 to 40 minutes and then raising the temperature to 32° C by adding warm water. Knoess et al. (1986) also made butter and ghee from camel milk. The milk was boiled, cooled, mixed with starter culture and left for one night. The watery sour milk was then churned for 30 minutes with an electric churner in a big earthenware vessel. During churning, cold water was added to increase the yield of butter. The buttermilk collected had a fat content of 0.72 %.

Experiments on butter manufacture from camel milk were carried out by Farah et al. (1989) in rural areas in North Eastern Kenya. Milk was heated to 65° C and separated with a hand centrifuge. The fat content of the cream obtained was then adjusted to concentrations varying between 20 and 30 %. Afterwards the cream was churned at temperatures between 15 and 36° C. After churning, the butter was washed with water at ambient temperature (27° C). The highest recovery of 85 % of butter fat, calculated on the basis of milk fat, was obtained at a churning temperature of 25° C and from cream with 22.5 % fat. The time needed to churn at this temperature was 11 minutes.

As already stated, butter is not a traditional camel milk product. In the nomadic societies butter is usually obtained from cow, goat or sheep milk. In the urban areas where the majority of the population lives, the butter consumed is from dairy plants. It is a luxury item and affordable only by a small proportion of the population living in the major cities.

The above-mentioned studies show that butter can be made from camel milk. The method is simple and can be performed on-farm or in centralized small-scale units in areas of large camel population. Production of butter on a commercial scale can be combined with the production of fermented milk. For this, the skim milk resulting from the separation and butter milk from churning, together with whole milk, can be used to manufacture cultured milk. Introducing small-scale units for camel milk processing will certainly promote camel dairying, generate income and contribute towards the improvement of the nutritional situation.

6.2.1 Technologically relevant properties of camel milk fat

For characterisation of milk fat, certain well-known physical and chemical fat constants are used. These constants serve as a general indication for fatty acids present in fats. They also enable detection of fat adulteration. Some of these constants for camel and

cow milk fat are presented in Table 6.2. Compared with cow milk fat, the fat of camel milk has low Reichert-Meissel, Polenske and saponification values, and higher melting point, refractive index and iodine value.

Table 6.2 ***Physical and chemical constants of camel butter***

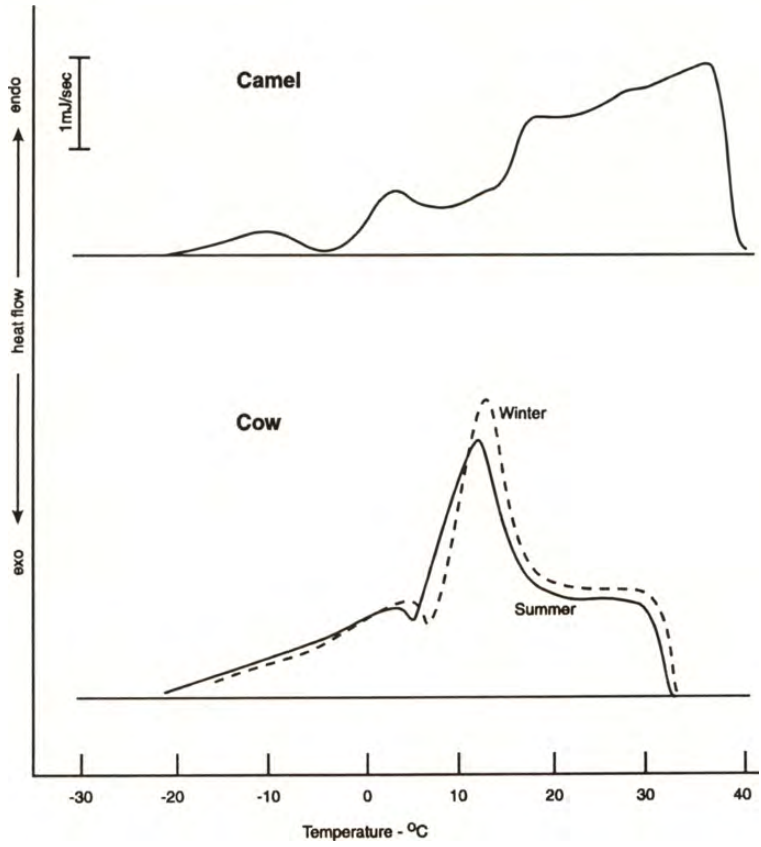
Constants	Camel milk fat				Cow milk fat
	Abu-Lehia (1989)	Farah et al. (1989)	Orlov (1984)	Purchase (1943)	various sources
Saponification value	201.8	200	200	217	220-233
Iodine value	43.8	49.0	55.0	43.8	25-28
Melting point (°C)	41.9	41.4	41.4	44.1	28-38
Refractive index	1.4567	1.4568	1.4490	1.4588	1.4558
Polenske-Value	-	0.62	-	0.50	1.5-5
Reichert-Meissel value	-	2.12	-	1.1	24-34

The lower Reichert-Meissel, Polenske value and saponification value as well as the higher iodine value of camel milk fat reflects its higher content of long chain fatty acids (C_{14}-C_{18}) and lower content of short chain fatty acids (C_4-C_{12}). This confirms the analysis of fatty acid composition present in Tab. 3.6.

Milk fat has no sharp, well-defined melting point, and melts over a wide temperature range. Generally, milk fat is liquid at and above body temperature and completely solidified below -40° C. At intermediate temperatures it is a mixture of solid and liquid triglycerides. The content of solid fat in the mixture is an important parameter for the rheological properties of milk fat. Information about the ratio of solid to liquid fat in camel milk is scarce and the only available work is the study of Rüegg and Farah (1991). In this study the melting thermograms and ratios of solid to liquid in camel milk fat were determined by differential scanning calorimetry (DSC). The melting thermograms were recorded in the temperature range -50 to 50° C. Melting started around -26° C and was complete below 43° C. Fig. 6.1 shows typical melting thermograms obtained with dehydrated butter fat prepared from camel and bovine milk. The thermogram for camel fat differed in shape and did not show the peak around 15° C which is typical of the middle-melting fraction of the cow milk

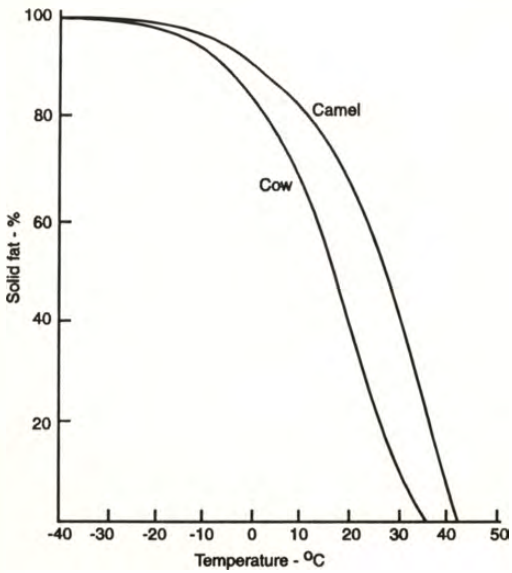
triglycerides (Timms 1980). The different amounts of low, medium and high melting fractions of triglycerides are consistent with the differences in the fatty acid composition between cow and camel milk . In camel milk fat the proportion of high melting fractions is high and those of low and medium melting fractions are low compared with cow milk fat.

Fig. 6.1 ***Differential scanning calorimetry thermogram of butter fat. (a) camel, (b) cow. (Rüegg and Farah 1991).***



From the typical curve for camel and cow milk fat, as shown in Fig. 6.2, the difference in churnability between camel and cow milk fat can be explained. It also becomes evident that butter from camel milk contains a significantly higher portion of solid fat over the entire melting range relative to butter from cow milk. At around 25° C, i.e. the temperature which gave the best churning results, 35 % of the fat was still liquid. Temperatures commonly used for churning cow milk cream are in the range 10 to 14° C. It is interesting to note that at the best churning temperature both camel and cow milk cream have similar proportions of liquid fat, e.g. about 35 %. At the optimal churning temperature for cow milk cream of 10 to 14° C, the distribution between liquid and crystalline fat is approximately equal.

Fig. 6.2 ***Melting curves of camel butter fat compared with typical curve for bovine butter fat. Percentage of solid fat as a function of temperature (Rüegg and Farah 1991).***



6.3 Cheese

In the nomadic societies there is no tradition of making cheese from camel milk. Like butter, cheese is exclusively obtained from goat, sheep and cow milk (Gast et al. 1969; Yagil 1982).

Despite the coagulation properties of camel milk (section 4) which seem to be unfavourable for cheese production, some promising studies can be reported. One of the earliest attempts to make cheese from camel milk was carried out by Purchase (1943) in North Eastern Kenya. Several attempts were made to clot camel milk with rennet which all failed to produce satisfactory curd. After that, the milk was soured naturally for a few days and the curd then pressed. The cheese was afterwards ripened in a cold chamber at 5 to 10° C. At the end of two months, the cheese developed a good green venation due to *Penicillium roquefortii*, originating from contamination in the ripening chamber. The cheese was granular, friable and had a fully developed flavour with some slight bitterness. No information was given on composition or yield.

Mohammed et al. (1990) described a method for making soft and hard cheese from camel milk. Milk was warmed to 32 to 35° C in 30 minutes, whey culture and rennet were added and after 30 to 35 minutes the curd was cut and stirred for 10 to 15 minutes. The temperature was then raised to 42° C, held for 30 minutes and the curd was scalded for 15 minutes by heating to 52° C. The curd was collected in cloth, pressed and transferred into steel hoops where it was further pressed for about 6 hours. The cheese was then pressed with wooden bands for about 18 hours at 22° C. Dry salt was rubbed on the surface of the cheese, the cheese was left for 24 hours and then placed in the brine (15 %, 10° C) for a week after which it ripened for 5 days at 18° C. It was turned every day and then removed to another ripening room and kept for five days at 12° C and then stored at 8° C. The cheese yield from 100 l of camel milk was about 5 kg. The characteristics (texture and hardness) of the cheese closely resembled those of Grana-cheese.

Cheese has been also made from camel milk by Kamoun and Bergaoui (1989, 1990). After heating the milk to 62° C for 2 minutes, calcium chloride (10 g/100 l) and lyophilised mesophilic starter culture (2 g/100 l) were added and the milk was ripened for 60 minutes. At 35° C rennet (20-30 ml/100 l) was added, the curd was cut after 60 minutes and allowed to settle for 4 hours after which it was

pressed and salted. By this method a soft cheese was produced and the yield from 100 kg milk was 12 kg of fresh cheese and 4.5 kg of the ripened cheese.

Ramet (1991) reported on manufacturing the following cheese varieties from camel milk: Fresh cheese, soft cheese, blue cheese, pressed cheese (Gibneh-type) and whey cheese (Ricotta-type). Calf rennet, mesophilic starter culture and clotting enzyme from *Mucor miehei* were used for coagulation. Calcium chloride and calcium phosphate were also added to the raw milk. A cheese manufacturing procedure usually applied to cow milk was followed. However, some modifications were necessary to improve the normally weak curd and texture of camel cheese. The cheese obtained was of good organoleptic quality, but the yield was low, compared to cheese made from cow milk, varying between 6.9 to 9.6 and 3 to 3.4 kg per 100 l milk fresh and after ripening, respectively.

During field studies in Kenya, Vikas and Farah (1991) made semi-hard cheese from camel milk. The milk was pasteurized at 65° C for 30 min on a wooden fire, cooled to 35° C followed by addition of 5 % mesophilic starter culture and citric acid (up to 0.25 g/l milk) until the milk reached pH 5.6 to 5.7. Rennet was added at 35° C. The curd was cut after 40 min and the temperature raised to 45° C in 20 to 30 min. The curd was then collected in cloth, pressed and placed in brine solution (10 %) for 2 hours. The cheese was put in a ripening room (18° C, 95 % RH) and brushed with brine solution twice a day for 2 weeks. The cheese was of pleasant appearance and the taste was comparable to Blue Cheese or Limburger. It became slightly bitter after 3 weeks of storage at ambient temperature (25-28° C).

Mehaia (1992) reported on manufacturing fresh soft white cheese from camel milk, following the procedure of manufacturing Domiati-type cheese. Different percentages of fat, salt and two lactic starter cultures (yoghurt and mesophilic starter cultures) were used. The yield was highest with cheese of 3 % salt and 1.5 % fat. This cheese was also the most acceptable in sensory evaluation. The yield of fresh cheese, however, was low, varying from 10 to 12 kg per 100 l milk.

The main difficulties encountered in manufacturing cheese from camel milk are the weak curd and the low yield. Problems associated with curd firmness in camel milk have been discussed in section 4. The cheese yield potential depends on the concentration of components in milk. The composition of milk is determined by species, breed, stage of lactation, age, seasonal changes in climate, type of feed, health conditions, especially mastitis, and milking procedures. Within the milk components the concentration of casein and fat are the major determinants of cheese yield. As shown in Table 3.1, the total casein content in camel milk varies between 1.9 and 2.3 % and is lower than that of cow milk (2.8-3.2 %). There is also a difference between camel and cow milk regarding the dimension of the casein micelles. As pointed out in section 3.1.3, the size distribution of casein micelles in camel milk is significantly broader than that of cow milk with a greater number of large micelles of 350 to 500 nm. As shown by Grandison (1986), micelle size is an important property of the milk with respect to cheesemaking. Smaller diameter micelles give firmer curd than larger micelles at the same total casein. Similar results were obtained by Niki and Harima (1984), who showed on the basis of evidence from electron micrographs that smaller micelles form a more compact and hence firmer gel network. From the work of McGann et al. (1980) and Dalgleish et al. (1981) it is known that smaller micelles contain a larger proportion of κ-casein. It seems likely, therefore, that increased κ-casein favours the formation of a firmer gel network by raising the amount of positively charged, hydrophobic para-κ-casein on the surface of the micelles. This difference between cow and camel milk in both concentration and dimension of casein might be the reason for the low curd firmness and consequently the low cheese yield in camel milk. As regards the fat, it is reported (Table 2.2) that the fat concentration in camel milk is similar to that in cow milk, varying between 3.2 and 3.8 %. However, as shown in Table 6.3, about half of the fat in the camel milk cheese is lost in the whey during draining. During the cheese making process fat globules are normally entrapped in the reticulum of the curd and block the flow of whey through the network. Owing to the loose network of camel casein matrix, most of the fat globules pass through the curd reticulum and can not be retained, leading to loss of cheese yield and quality.

Table 6.3 ***Fat content in camel cheese***

% Fat		References
Raw milk	**Whey Cheese**	
4.2	2.2	Mohammed et al. (1990)
3.1	1.5	Kamoun and Bergaoui (1989)
2.7	1.3	Ramet (1991)
Values in cow milk cheese	0.2-0.6	Puhan (1993)

Adjusting camel milk to particular casein: fat ratios may improve cheese yield. Application of new processes such as heat treatment or membrane concentration of milk prior to cheese making can also be considered. However, many studies still have to be undertaken to optimize yield and quality of camel milk cheese.

6.4 Pasteurized milk

Nancy Abeiderrahmanne (1994), a Mauritanian engineer, founded the first milk processing plant for pasteurized camel milk in Africa in Nouakchott, Mauritania. The plant is equiped with an Alfa Laval Microtherme plate pasteurizer and a NOVA packaging machine. The milk is packaged in Variopak gable-top cartons. The filling rate for 0.5 litre packs is 900 packs per hour. The plant's nominal capacity is 600 litres per hour, but it processes 3000 litres of camel milk per day.

Milk is supplied by a number of herdsmen who were already supplying milk to raw milk retailers in the town. Because of the need to make the maximum use of the available grazing and to avoid the unhealthy conditions of the urban environment, the herdsmen move away from the town, sometimes up to a distance of 100 km. This makes milk collection very difficult as the suppliers have to be located every day while they are on the move.

The dairy has its own vehicles for milk collection and the churns are supplied and cleaned by the dairy. The herdsmen are paid every day. In certain periods the dairy buys feeds in bulk and sells them to the herdsmen at the same price, granting them credit which can be paid back by deduction from the price of the milk. This very short term credit is intended to give the herdsmen a sence of loyalty and security. The dairy has a number of vehicles which deliver milk directly to a network of shopkeepers which have refrigeration facilities and the dairy covers the entire town.

During the first two years the dairy was confronted with milk collecting and marketing difficulties and it was hard to obtain steady milk supply and demand due to seasonal milk fluctuation. To compensate for the fluctuation the dairy introduced pasteurized cow milk beside camel milk and there are also plans to manufacture cheese with surpluses of camel milk.

7 Processing options for camel milk: Field studies in north eastern Kenya

7.1 Introduction

In East Africa, where 60 % of the camel population are held, the consumption of camel milk is not limited to the pastoral nomads, but camel milk is commercialised and also sold in the urban areas. These traditional dairy systems can be the basis for a dairy processing camel milk, particularly in countries where large camel populations are found.

However, research on camel milk conducted during the past two decades has had very little, if any, impact on upgrading the existing dairy systems. As a part of the camel milk research programme going on at the Swiss Federal Institute of Technology in collaboration with the University of Nairobi and Ol-Maisor Camel Farm in Rumuruti, Kenya, field studies in north-eastern Kenya have been undertaken to examine the potential of small scale dairy processing for camel milk products. Based on the results of the field studies, proposals for the promotion of a camel dairy in rural areas around Garissa, north-eastern province of Kenya, have been worked out. These proposals are presented in the following sections.

7.2 Location of the field study

The experiments were performed in the field station in the town of Garissa, the administrative centre of the north-eastern province of Kenya. The majority of the camel population in Kenya is concentrated in this province. Apart from a relatively narrow fertile band along the Tana River, this region is rather arid and consists predominantly of desert and grassland with average annual precipitation of 150 to 400 mm. The population is mainly made up of Somali nomads, who move from one grazing area to another with their mixed herds of camels, cattle and goats, and semi-nomads who spend part of each year in centres such as Garissa, living mainly from trade in animals.

7.3 Milk supply

The camel milk suppliers are the nomadic pastoralists. Traditionally nomadic settlements are transient and their movements depend on where they can find adequate pasture and water for their herds.

This picture of „moving" nomads has changed to a certain extent in recent decades. With growing urbanisation the demand for milk among the city population has been increasing. On the other hand the demand for a number of goods such as grain, oil, sugar, clothes and other „things of the town" increased among the pastoralists and the milk sales became the most important part of cash income of many camel owning pastoralists. (Samantar, 1987; Herren, 1992). To ensure a steady supply of camel milk to the market, a new system of camel milk marketing has emerged. However, the mechanism of this system — from milk production through transportation and price-setting — is fragmentary and often difficult to obtain.

Most of the camel milk sold in urban centers in the north-eastern of Kenya comes at present from more or less permanent nomadic settlements around water boreholes as far as 50 km from the towns. The milk is brought to collection points along the roads and sold to urban market traders who transport and commercialise the milk. In wet seasons when camel milk is abundant, nomadic women may bring milk to the urban centers themselves.

7.4 Milk collection and location of the dairy plant

Whenever possible, the dairy plant should be located near the suppliers. Close proximity of milk production and milk transportation allows milk to be collected without refrigeration which is always expensive and unreliable in developing countries. However, it is not always possible to put the dairy plant near the milk suppliers as the location of a dairy plant is also dependent on other factors such as transportation facilities and water supply. Taking into account the existing structure of the camel milk market, the best way to ensure a reliable supply is that suppliers deliver milk directly to the dairy plant.

It is advantageous if the milk is delivered at the processing center directly by the producer. The dairy personnel can check the quality of the milk in presence of the producer and, if necessary, sort out bad quality from good quality. This helps not only to collect the milk according to its quality but also to instruct the producer how to deliver good quality milk. This personal contact between milk producer and milk processor is extremely valuable.

Milk hygiene and quality control are an important part of the milk collection. At present it is not known to what extent the methods for quality control normally applied for cow milk can also be used for

camel milk. Therefore, we recommend the use of the quality tests generally used for cow milk but specially adapted for conditions in warm developing countries (Bachmann 1992). In the region Garissa where the field study was carried out, most of the potential milk suppliers live round the town at a distance between 10 and 20 km along the Tana river where the nomads keep their camels. Due to the availability of water, electricity and the vicinity of milk suppliers the town of Garissa is considered to be the ideal place to build the camel milk processing unit.

7.5 Products

Any dairy products to be introduced must be based on the already existing traditional products in order to have a chance of being accepted. Most of the camel milk is consumed in the form of fermented milk. The milk is allowed to ferment naturally at ambient temperature and without prior heat treatment until it turns sour. The resulting fermented camel milk is known as „Susa". Due to the spontaneous nature of the fermentation, this traditional method results in a product with varying taste and flavour and is often of poor hygienic quality. In addition, because of the limited scale of production, the product can be sold only in the immediate vicinity of the herd. To produce fermented milk under controlled conditions, thermophilic or mesophilic lactic acid cultures are normally used. In warm countries, mesophilic lactic cultured milk offers the advantage that it can be incubated at the ambient temperature of 20 to 30° C. The field study in north-eastern Kenya showed that the traditional „Susa" can be improved by using selected mesophilic lactic acid cultures.

During the field study a simple method was developed which allows butter to be obtained from camel milk. Camel milk butter is not a traditional product. In general, butter in Kenya is a luxury item, although it could be of great nutritional importance. In particular, in the Garissa region, it is only affordable for a small proportion of the population, as it originates from dairies in the Nairobi area and must be transported by road over a difficult 400 km route, which greatly increases the retail price. The process developed for producing camel milk butter, therefore, met with great interest among the population.

7.6 Dairy plant

The primary aims of processing camel milk are the creation of additional income for camel-owners and milk-traders as well as the production of valuable food for self consumption. Of all milk types, camel milk is the one available all year round in north-eastern Kenya although in greater quantities in the wet season than in the dry season. In our field study we have not investigated whether there is a demand for processed camel milk. Nevertheless, according to our discussions with different population groups from rural and urban centres we assume this to be the case. Our assumption is based on the following arguments: Camel milk is the most appreciated milk. Both rural and urban populations are eager consumers of camel milk. The motivation for drinking camel milk arises not only from the nutritional value but from traditional value surrounding all that comes from the camel. In the investigated area in and around the town of Garissa, camel milk consumers can roughly be divided into two groups: private householders and establishments such as hotels, restaurants and government institutions. The former buy their milk from the market, the latter buy mainly processed cow milk (milkpowder, butter, UHT-milk) from milk factories in Nairobi about 500 km from Garissa. This group buys processed cow milk products owing to their higher hygienic level and longer shelf life than camel milk, although these consumers would prefer to buy processed camel milk if it were available. During our field study we could not get reliable information on the amount of camel milk available for processing and the amound of funds obtainable for capital investment to set up the plant.

Under these circumstances two dairy plants with different capacities have been proposed. A small dairy which has the capacity to process 500 to 1000 litres of milk per day and a medium scale dairy plant for 2000 to 3000 litres per day. Detailed processing methods for manufacturing fermented milk and butter have been published by Farah et al. (1989, 1990), Hangarter and Farah (1989). In the following only the basic operations are described.

7.6.1 Small scale dairy plant, daily capacity 500 to 1000 litres

The plant is small and can be located almost anywhere as long as there are water facilities. The equipment used is simple and straightforward. The dairy is intended to produce only the fermented milk „susa". The milk in a 40 to 50 litre churn is heated in a cooker by a

wood-fired water bath. When the temperature reaches 85 to 90° C, the churn is lifted from the cooker and put into an insulated box for 20 to 30 min. Solar heating systems can also be used if the milk is to be heated to 65° C for 30 min.

After pasteurization the milk is cooled to 22 to 25° C° C and inoculated with mesophilic starter culture. The cooling is performed by placing the milk churn in a water bath. The water is recooled by circulation through a cooling tower. The water is circulated by hand pump. The milk is incubated for 24 hours in the water bath. Obtaining starter cultures could be a limiting factor for large scale production of fermented milk. However, simple commercial systems for producing frozen starter cultures which maintain their activity for years are in operation in Kenya (Kurwijila 1983; Schulthess 1988).

For packaging, polyethylene bags of half litre capacity can be used as they are cheap and locally available. For sealing the bags, a hand operated heat sealing unit, which is also locally available, can be used. An alternative to the plastic bags is to sell the milk in the milk churns used in the processing. This would be cheaper both to the dairy and the consumer. The consumers would then have to bring their own vessels at purchase. This is the way camel milk is sold on the market and it would not be very much of a change for the consumer.

7.6.2 Medium scale dairy plant, daily capacity 2000 to 3000 litres

A medium scale dairy plant can be considered if sufficient milk and capital are available. The dairy is mainly for production of fermented milk „susa" but can be combined with the production of butter or ghee which can be sold at a higher price than fermented milk. This will help to maintain a low price for fermented milk and encourage its consumption on a wider scale.

The fermented milk can be processed in a batch pasteurizer which is locally available. The pasteurizer is equipped with a heating coil for warm water or steam and a second coil for cooling with tap water. The batch pasteurizer is also equipped with a mechanical stirrer. If electric power fails, stirring can be performed manually. Milk is charged into the pasteurizer and withdrawn manually or by gravity. The use of milk pumps is avoided as far as possible. Heating-water and cooling-water is pumped. The water circuit is equipped with hand-operated stand-by pumps. If the batch pasteurizer is used for low-temperature pasteurization (63° C for

30 min), warm water from a solar heating system can be used. For manufacturing butter, the milk is heated to 65° C and separated with a hand centrifuge. In our field study, the highest recovery of 85 % of butter fat, calculated on the basis of milk fat, was obtained at a churning temperature of 25° C and from cream with 22.5 % fat. The time needed to churn at this temperature was 11 minutes. For churning and moulding the butter, wooden barrels and hand tools can be used. They can be manufactured locally by skilled carpenters. For manufacturing ghee, various models of melting vats, which allow separation of the aqueous sediment from the butteroil are locally available.

7.7 Concluding remarks

The model for a camel milk processing plant proposed here is planned according to the specific situation in Garissa. The small scale dairy plant (500-1000 l/day) for fermented milk proposed enjoys a number of advantages which would allow smallholder camel owners to commercialize milk which would otherwise not normally be marketed. These advantages include no dependency on electricity, simple production techniques and a familiar product that appears to enjoy a good market. The medium scale dairy plant is more energy and capital intensive but most of the necessary equipment is available in Kenya. However, detailed studies on milk production potential, organizational structure and financial feasibility are required. Furthermore, the observed demand for processed camel milk has to be confirmed.

8 Conclusions

The aim of the present book is to bring together as much information as possible on the use and properties of camel milk. Research on camel milk was limited until the early seventies to studies on general composition and milk yields. Since the early eighties the interest in studies on physico-chemical properties of camel milk as well as technological problems associated with its utilisation has been growing. However, such studies are still fragmentary and by no means systematic. Much of the work so far has been carried out by individuals with little institutional support. Thus, the research has tended to remain isolated with little impact on dairy camel production. The wide dispersal of pastoralists in the arid areas has certainly made it difficult to develop a proper camel dairy system. however, in countries with large camel populations such as Somalia, Kenya and Ethiopia there is a growing demand for camel milk in the rural and urban centres. This has stimulated owners to transport camel milk in small batches by animals or lorry from as far as 150 km. The milk is marketed as sour milk. Most of this milk comes from semi-sedentary herds which are integrated into agro-pastoral systems. On the basis of this existing milk production system, an indigenous camel dairy industry can be developed. For this the following points are recommended:

- Studies on camel milk production are required. This means collecting data on supply and demand for camel milk as well as information on the seasonal variation of production. Should the market studies confirm the existence of a large potential for camel milk, specific grazing and management schemes should be worked out to protect both the environment and the pastoral societies themselves.
- Camel milk is either consumed or sold mainly as fermented milk, but in certain pastoral societies the milk is also converted to butter, ghee and cheese. Research is needed to improve these traditional methods to produce more stable and marketable products. This should allow smallholder producers to process surplus milk on farm or in centralised small-scale dairy units.

- Milk collection and processing should not imitate dairy systems of industrial countries in temperate climates. The dairy factories have to be situated in rural areas and should be built and equipped with locally available material and machinery. The products to be manufactured should be marketable without, or with only a very limited amount of, artificial cooling.
- Although camels give significantly higher and more reliable quantities of milk than cows in the same arid environment, camel milk production can be improved by upgrading the local stock through introducing high milk-yielding camel breeds reported in countries such as Saudi Arabia and Pakistan. However, such upgrading requires structured cross-breeding programmes including herd selection, disease control, milk recording, progeny testing and improved management.

In the past few years, with draught and the onset of desertification, most traditional types of livestock have suffered considerably. Camels suffer least and they have survived the crisis without the heavy losses that have occurred in other species. Today in East Africa the camel is replacing cattle in many areas. Stimulating camel milk production can therefore yield impressive results in terms of human nutrition and generation of cash income in the rural economy.

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In many arid areas, camels play a central role as milk suppliers. The comparative advantage of the camel as a dairy animal over the other species in the same environment is difficult to quantify; however, it is widely recognised that in absolute terms, the camel produces more milk and for a longer period of time than any other milk animal held under the same conditions. Research on camel milk was limited until the early seventies to studies on general composition and milk yields. Since the early eighties the interest in studies on properties of camel milk has been growing. However, such studies are still fragmentary and by no means systematic. This book attempts to fill a gap which exists in the literature. It provides a synthesis of existing knowledge on the chemical properties and physical characteristics of camel milk as well as technological problems associated with the utilization of camel milk. This has not been done before and it is true to say that no book of this nature, dealing especially with chemistry and technology of camel milk, has yet been published. The book draws on the author's experience in research on camel milk in many countries, including Kenya, Somalia, Ethiopia and Switzerland.

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