Production system, Phenotypic and Molecular Characterization of Sudanese Camels (*Camelus dromedarius*)

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Dedication

To my parents,

Wife (Sana),

And lovely daughters

(Tuga & Ganan)

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Abstract

The main objectives of the present study were to describe the conditions of camel production systems in Sudan and identify the breeding goals, husbandry practices and production constraints. A second objective was to characterize and describe some of the Sudanese camel ecotypes on the basis of their morphological traits. The study also aimed at identifying the allelic variants of the *growth hormone (GH)* gene in Sudanese camel ecotypes and estimating the correlations between body measurements and DNA polymorphisms of the *GH* gene.

A set of detailed structured questionnaires were used to collect information from 103 camel owners in some camel breeding areas (Sinnar, Gedaref, Gezira and North Kordofan states). The majority of camel owners in Sinnar, Gedaref and North Kordofan states indicated livestock breeding to be their main activity, while camel owners in Gezira state considered both livestock and farming to be their main activity. Sales of animals were important for obtaining regular cash income, in addition to sales of agricultural crops in the case of those who practiced crop production. Milk produced was used only for home-consumption. The serious production constraints as defined by camel owners were lack of feed, disease prevalence and water shortage. The priority of camel owners with regard to genetic improvement was to produce dual purpose animals for meat and milk production. Second on their list of priorities were meat animals and last were dairy animals. Racing ability was given a low priority.

Phenotypic measurements and description data were obtained on 274 camels from ten ecotypes. The results showed that average barrel girth, heart girth, height at shoulders and body weight were 2.45

± 0.02 m; 2.02 ± 0.01 m; 1.90 ± 0.01 m and 463.25 ± 4.90 kg, respectively. The results also revealed that phonotypic measurements were significantly influenced by type of camel and age group. The Shanbali camel recorded the highest values of barrel girth, heart girth and body weight, followed by the Kenani camel. Rashaidi, Annafi and Bishari camel breeds recorded the lowest values. Moreover, the results showed that the sex of camel significantly affected the heart girth, height at shoulders and body weight; and the males had significantly higher ($P < 0.5$) values than females. The phenotypic measurements data concluded that the Shanbali and Kenani camel breeds are the largest Sudanese camel breeds followed by Maalia and Maganeen camels. At the molecular level the study dealt with the identification of allelic variants of *growth hormone (GH)* gene and estimation of correlations between body measurements and DNA polymorphisms of the *GH* gene. The comparison of Sudanese camel *GH* sequence with that of the GenBank sequence identified one single nucleotide polymorphism (SNP) in the non coding region (intron 1) in position AJ575419:g.419C>T. A PCR-RFLP method was used to genotype 181 animals for the detected SNP. Bishari and Anafi breeds that are classified as riding camels had slightly higher T allele frequencies (0.57 and 0.48, respectively) than those of the other four breeds which are classified as pack camels. The effect of genotype with regard to the SNP g.419C>T on the body measurements was not significant ($P>0.05$). In the light of the study findings the shortcomings of the traditional classification of Sudanese camels were outlined and a new classification suggested. Recommendations for genetic improvement of camels based on the study findings were given.

الملخص

الأهداف الرئيسية من هذه الدراسة هي :

1- توصيف نظم إنتاج الإبل في السودان ، وتحديد أهداف تربية وتحسين الإبل، ومعوقات انتاجها.

2- توصيف بعض سلالات الابل السودانية وفقا لسماتها المظهرية.

3- التعرف على الاختلافات الأليلية لجين هرمون النمو في سلالات الإبل السودانية وتقدير الإرتباطات الوراثية بين القياسات الشكلية للابل وتعدد مظاهر DNA هرمون النمو.

صمم استبيان يحوي مجموعة من الاسئلة المفصلة والمنظمة بهدف جمع بيانـات عن 103 فرد من مربي الابل في بعض مناطق تربية الإبل بالسودان: وهي ولاية سنار، القضارف، الجزيرة وشمال كردفان. كذلك تمت زيارات الى منـاطق الإنتـاج وأجريـت مقابلات مباشرة مغ المربين. تم تحليل DNA مأخوذ من عينات شعر لعدد 181 فـردا من الابل لاقرابة بينها تمثل ستة سلالات من الابل السودانية وهـي: الكنانـة، اللحـوي، الرشايدي، العنافي، البشاري والكباشي.

أوضح معظم مربي الإبل بولايات سنار، شمال كردفان والقضـارف أن تربيـة الحيوانات هي النشاط الرئيسي لديهم، في حين أن غالبية مربي الإبل في ولاية الجزيـرة (سهول البطانة) يرون أن الزراعة و تربية الحيوانات معا تمثلان نشاطهم الرئيسي. تمثل مبيعات الحيوانات مصدرا مهماً للدخل النقدي المنتظم، بالإضافة إلـى بيـع المحاصـيل الزراعية بالنسبة للمربيين الذين يزرعونها، في حين أن اللبن المنتج يستخدم في أغـراض الاستهلاك المنزلي فقط.

كانت أهم معوقات الإنتاج التي ذكرها مربو الابل: نقـص الأعـلاف، وانتشـار الأمراض ونقص مياه الشرب. بين مربو الابل أن الأولوية في التحسـين الـوراثي هـي للحيوانات مزدوجة الغرض (انتاج اللحم واللبن) ثم الحيوانات المنتجة للحـوم فقـط ثـم الحيوانات المنتجة للبن فقط، في حين أن ابل السباقات نالت أقـل أهميـة فـي التحسـين الوراثي.

أخذت بيانات عن المقاييس المطهرية للجسم لعدد 274 رأساً مـن الابـل تمثـل عشرة أنواع من الابل السودانية. أظهرت نتائج هذه الدراسة أن متوسطات محيط البطن ،

محيط الصدر، الارتفاع عند الغـارب ووزن الجسـم كانـت 2.45 ± 0.02 متـر ؛ 2.02 ± 0.01 متر ؛ 1.90 ± 0.01 متـر و463.25 ± 4.90 كيلـوغرام، على التوالي. كما كشفت النتائج أن القياسات المطهرية تأثرت معنويا بنوع الابـل والفئـة العمرية. حيث وجد أن ابل الشنابلة سجلت أعلى قيم لمحـيط الـبطن (2.64 ± 0.04 متر) ، محيط الصدر (2.08 ± 0.02 متر) ووزن الجسـم (516.69 ± 12.48 كيلوغرام) ، وتلتها الابل الكنانية. بينما سجلت ابل الرشايدة، العنافي والبشاري أدنى قـيم لتلك القياسات. وعلاوة على ذلك ، أظهرت النتائج أن للجنس أثر معنويا($P < 0.5$) علـى محيط الصدر، الارتفاع عند الغارب ووزن الجسم، وسجلت ذكور الابل قيماً أعلى معنويا ($P < 0.5$) مقارنة بالإناث. تخلص نتائج القياسات المظهرية للجسـم أن ابـل الشـنابلة والكنانة هي أكبر سلالات الابل السودانية حجما وتليها ابل المعاليا والمجانين.

على المستوى الجزيئي تمت دراسة الاختلافات الأليلية في جين هرمون النمو في سلالات الإبل السودانية وتقدير الارتباطات بين القياسات المظهرية للجسم وتعدد مظـاهر DNA جين هرمون النمو. عند مقارنة تسلسل جين هرمون النمو للابـل السـودانية مـع التسلسل الموجود ببنك الجينات (GenBank) بالتسجيل AJ575419 ، تم الكشف عن وجود طفرة قاعدة واحدة (SNP) في المنطقـة غيـر المشـفرة (intron 1) فـي الموقع(g.419). واستخدمت طريقة تفاعل البلمرة المنسلسـل (PCR) مـع RFLP لمعرفة التركيب الوراثي لعدد 181 حيوان. أظهرت نتائج الدراسة أن تكـرار الأليـل Tفي سلالتي البشاري والعنافي والتي تصنف على أنها ابل ركوب كان أعلى (0.57 و 0.48 على التوالي) مقارنة بتكرارات الأليل في السلالات الأربع الأخرى التي تصـنف عادة على أنها إبل حمل. وكذلك برهنت الدراسة على عدم وجود ارتبـاط معنـوي ($P > 0.05$) بين التراكيب الوراثية لجين هرمون النمو والقياسات المظهرية للجسم وهي محيط البطن، محيط الصدر، الارتفاع عند الغارب ووزن الجسم. كما استنتجت الدراسة أن الإبل السودانية بإستثناء إبل البشاريين قد تكون انحدرت من أصل واحد وفي ضوء هذه الدراسة تبينت أوجه القصور في التصنيف المستخدم للإبل السودانية ونم إقتراح تصنيف جديد، كما أعطيت مقترحات للتحسين الوراثي.

Chapter one

Introduction

Camelidae provide humankind with a range of products and services, from fine wool to meat, milk and draught power. The ability of the Camelidae to go for long periods without water and live on thorny and high-fiber diets, stand high altitudes, and extreme temperatures, make them one of the few families well adapted for food and agricultural production under harsh semi-desert environments. The desert areas are characterized by scarcity of food resources necessary to maintain life of man, animals and plant. In those critical situations, camels play a major role in providing nourishment and livelihood for mankind, at times when other livestock classes can not survive. The camel possesses certain unusual physiological features that enable it to thrive in extremely arid environments (Gihad, 1995). Camels have fascinated mankind both by their appearance and ability to survive in a harsh environment, often without food and water for long periods (Wilson, 1984).

Camel population in the world is estimated at 18.5 million heads. Dromedary camels comprise 95% while, the remaining 5% are Bactrian camel. Bactrian camels are found mainly in the cold high altitude of Asia. The Near East, North Africa and the Sahel Region have about 70% (12.6 million) of the world's dromedary camels. Somalia and Sudan together own about half of this number (Kesseba *et al*., 1991). Sudan is rated the second in numbers of camel population in the world. Camels constitute 22% of the animal biomass in Sudan and 26.3% of the numbers of camel in the Arab world (Sakr and Majid, 1998). The estimation of camel's population in the Sudan

was about 3908 thousand heads (Ministry of Animal Resources, 2005). Theses Camels are spread in a belt that extends between latitudes 12◦N - 16◦N (Wardeh, 1989)

Despite the fact that camels are a major component of the agro-pastoral systems in vast pastoral areas in Asia and Africa, little is known about their production potential and production systems compared to other domestic animals. However, previous research conducted on camels dealt mostly with disease problems, reproductive physiology and characterization (Mehari *et al*., 2007). This research was initiated in order to investigate the camel production systems and conditions and identify breeding goals of camel owners and production constraints as an essential step towards development of a sustainable breed improvement program. Moreover, the genetic characterization of camels is of paramount importance to supplement other characterization information obtained from phenotypic descriptions and measurements. Such information will aid in the design of improvement programs (Correlations between phenotypic and genetic markers) and in taking decisions regarding conservation policies.

Genetic polymorphisms are playing an increasingly important role as genetic markers in many species of animals and camels are no exception. With the development of molecular genetic techniques, it has become possible to establish a new class of genetic markers based on variability of DNA at the sequence level (Chung *et. al.* 1998). The analysis of microsatellite alleles, polymerase chain reaction and restriction fragment length polymorphism (PCR-RFLP) provide the possibility of the practical application of polymorphic genetic markers to livestock improvement (Soller and Beckmann, 1982). The

discovery of RFLP renewed the interest in the use of genetic marker loci as an aid to selection programs. If one (or several) of these RFLP markers are associated with economic trait loci, they can be used as selection criteria. In a breeding scheme, use of phenotypic data coupled with genetic marker data provides more information than phenotype data alone. The use of information on genetic markers is expected to increase genetic progress through increasing accuracy of selection, reduction of generation interval and increasing selection differentials (Soller and Beckmann, 1983; Kashi *et. al*., 1990; Meuwissen and Van Arendonk, 1992).

The purposes of this study were to:

1- Collect information on conditions of camel production systems in Sudan and to identify breeding objectives of camel owners, husbandry practices and production constraints.

2- Characterize and re-grade some Sudanese camel breeds according to their morphological features.

3- Sequence the *growth hormone* (*GH*) gene in Sudanese camel breeds looking for single nucleotide polymorphisms (SNPs) and estimating correlations between body measurements and SNPs of *GH* gene.

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Chapter two

Literature review

2:1 Historical Background:

Camels belong to the family *camelidae* and hence to the suborder *tylopoda*. The *tylopoda* themselves belong to order *artiodactyla* or cloven-footed animals. The family *camelidae* has two Old World (tribe *camelina*) species, bactrian camel (*Camelus bactrianus*) and dromedary (*C. dromedarius*), and four New World (tribe *lamini*) species, guanaco (*Lama guanicoe*), llama (*L. glama*), alpaca (*L. pacos*) and vicuna (*L. vicugna* or *Vicugna vicugna*) at the present time (Novoa, 1989 and Stanley *et al*., 1994). According to the fossil records, *camelidae* evolved in North America during the Eocene, approximately 40–45 million years ago (Stanley *et al*., 1994), and the division between *Camelini* and *Lamini* occurred in North America about 11 million years ago (Harrison, 1979 and Webb, 1974). In the late Tertiary (the epoch Pliocene) the species of *Camelini* and *Lamini* migrated from North America to South America and Asia separately, and their ancestors became extinct in North America subsequently.

The domestication of the camel occurred relatively recently compared with other animals, such as, sheep (10000 B.C.), goats (8000 B.C.), pigs (6500 B.C.) and cattle (5000 B.C.), (Planhol and Rognon, 1970). Opinions on when camels were first domesticated differ widely, Free (1944); Zenner (1963); Ripinsky (1975) and Bulliet (1975) believe that camels were domesticated before 2000 B.C., while, Epstein (1971) taking into account the earliest Egyptian and Mesopotamian archaeological evidence, dated domestication as

early as the fourth millennium B.C. However, Walz (1956) believed that camels were domesticated perhaps during the 13th or 12th century B.C., but not before 2000 B.C.

The history of the dromedary camel in Sudan is even more obscure. It is believed to have entered the Sudan from Egypt. A specimen of camel hair rope of the old kingdom was found at Fayum in Upper Egypt, dating about 2980-2475 B.C., indicating that the animals have moved south by that period. In Sudan, the oldest evidence is a bronze figure of camel with saddle found at Merawi, and estimated between 25-15 B.C. (Adison, 1934; Robinson, 1936). Tracking of historical trends in the Sudan is difficult because of lack reliable data (Romet, 2001). Probably the camels entered the Sudan through the following routes:

1. North West Africa route during 4th to 6th century.
2. Egyptian route.
3. Red Sea route (most recent). (Salman, 2002)

2:2 Camel population and Distribution:

It has always been difficult to make reasonable estimates of camel numbers in the world, mainly because camels exist in desert areas with difficult accessibility. Ramet (2001) reported that from 1950-1980, there was a decrease in the numbers of camels, for several reasons such as mechanization of transport, sedentarization of nomads and exceptional droughts.

Camelus dromedarius (dromedary or one-humped camel) is adapted to hot and dry conditions, whereas *Camelus bacterianus* (bacterian or two-humped camel) is adapted to cold and dry conditions (Smuts and Bezuidenhout, 1986). Camel population in the world is estimated at 18.5 million heads of which dromedary camels comprise

95% while the remaining 5% are Bactrian camel. Bactrian camels are found mainly in the cold high altitudes of Asia. The Near East, North Africa and the Sahel Region have about 70% (12.6 million) of the world's dromedary camels. Somalia and Sudan together own about half this number (Kesseba *et al*., 1991). Schwartz and Dioli, (1992) reported that the camel is most numerous in the arid areas of Africa (approximately 11.5 million animals in this region in 1992), particularly in the arid lowlands of Eastern Africa (Somalia, Sudan, Ethiopia, Kenya and Djibouti).

Sudan is rated the second in numbers of camel population in the world. Camels constitute 22% of the animal biomass in Sudan and 26.3% of the numbers of camel in the Arab world (Sakr and Majid, 1998). The last estimate of camel's population in the Sudan was about 3908 thousands head (Ministry of Animal Resources, 2005). Table 2.1 shows the distribution of camels in the different states of Sudan. Growth rate of camel's herds in Sudan is 1.4% (Babiker, 1988).

Camels in Sudan are spread in a belt configuration that extends between latitude 12◦N to 16◦N (Wardeh, 1989). This belt is characterized by an erratic rainfall of less than 350 mm. Agab (1993) mentioned that camels in Sudan are concentrated in two main regions; the Eastern States, where camels are found in the Butana plain and the Red Sea mountains, and Western regions (Darfour and Kordofan). In the Butana area of Sudan camels are commonly raised under nomadic conditions in a geographical zone, which is located approximately between latitude 14◦N to 16◦N and Longitude 33-36◦ E. Al-Amin (1979) reported that diseases such as trypanosomiasis and the unsuitability of the clay soils prevented migration of camels into southern parts of Sudan.

The rainfall in Butana zone is low to moderate. Vegetation consists of semi-desert grassland on clay in the North and on area of rich savannah with acacia thorn-land on dark cracking clay, alternating with grass area in the South (Abu-sin, 1997). Butana is inhabited by different camel owing tribes such as Shukria, Lahween, Kawahla and Rashaida. These tribes are ancient camel breeders and have maintained a pastoral mode of life for centuries. Due to fluctuations in rainfall and the scarcity of pasture especially in the dry season (Nov.-July) these tribes, practice a transhumant mode of range utilization (Abbas *et al*., 1992).

Table 2.1: Distribution of camel in Sudan according to states.

State	Camel numbers	Camel population %
North Kordofan	738221	18.89
South Kordofan	198526	5.08
West Kordofan	501787	12.84
North Darfour	484592	12.40
South Darfour	91447	2.34
West Darfour	350157	8.96
Elgadaref	202434	5.18
Kassala	526408	13.47
Red Sea	273951	7.01
Blue Nile	175078	4.48
Sennar	95746	2.45
Algezira	101217	2.59
White Nile	28919	0.74
Northern	40252	1.03
River Nile	93792	2.40
Khartoum	5471	0.14
Total	3908000	100

Source: Ministry of Animal Resources (2005)

Greater Kordofan state is considered the leading state in camel population in the country (Table 2.1) with 1.5 million heads comprising 36% of the total camel population in the Sudan (Sakr and

Majid, 1998). Their domain is the most marginal lands, characterized by erratic and scantly rainfall, dry steppe, sand dunes soil with patches of hills and stony features.

Camel herders are continuously on the move seeking grazing and water. The camel migration patterns in Eastern Sudan are different from those of Western Sudan; the distances traveled in the east are shorter and the area is not as arid as that of Western Sudan (Al-Amin, 1979).

2:3 Classification of dromedary camels:

Unlike other conventional farm animal species, the camel has not been subjected to intensive selection to perform certain physiological functions such as milk or meat production. The selection criteria used by nomads were more oriented towards ensuring survival in a harsh environment, speed, and other aesthetic characteristics that vary from one tribe to the other.

Camels can be grouped into Mountain Camels and Plains Camels, with the first category subdivided into Baggage (pack) and Riding Camels and the latter category subdivided into Desert and Riverine Camels (Leese, 1927) (Novoa and Wilson, 1992; Köhler-Rollefson, 1993). Gillespie (1962) reported that the camels are mainly classified into two types: pack and riding. Arabian camels can be classified according to tribes, animal color and regions. Djemali and Alhadrami (1991) mentioned that these classifications assign little importance to the main products (milk and meat).

A new classification divides camels into four major classes: beef, dairy, dual purpose and race camel. This classification is based on the fact that the camel is a major component of the agro-pastoral systems in Asia and Africa (Wardeh, 2004).

2:4 Classification of Sudanese camels:

Camels in Sudan are classified as pack (heavy) and riding (light) types according to the function which they perform (Gillespie, 1962). The riding camel has received more attention and has undergone intensive selection. The following classification is based on conformation and tribal ownership.

2:4:1 Pack camel:

This comprises 90% of the total number of camels in Sudan. It is characterized by large, heavily built body, with capacity for developing a relatively large hump and includes the following types:

A. Arabi camel: is a sandy, gray, large, heavily built animal with a well developed hump. It is widely distributed in the Sudan due to its good performance as work animal. Arabi camel is subdivided into three breed types.

I. Light Pack: Found east of the Nile and in the area of the red sea bred by Hadandwa, Beni Amer and Al-amarar tribes.

II. Big Arabi: Spread in Butana region and bred by Shukria, Bataheen and Lahaween tribes in western Sudan.

III. Heavy Arabi: It is characterized by its heavy weight, big hump, long neck, big head, roman nose, heavy bones, its sandy gray or fawn color, usually with long hair on the hump and the shoulder (Al-Khouri, 2000). Size wise it is known to be the largest camel in the Sudan. Its homeland spreads in the desert and semi-desert areas west of the Nile River. This type includes Kababish camel which is found in Northern Kordofan.

B. Garbawy and Fiesani camels: These are found mainly in Northern Darfour province (Zayed *et al*., 1991).

C. Rashaidi camels: This type is pinkish-red in colour, slightly shorter, not quite as heavy as Arabi camel types and less numerous. Rashaidi camels are herded mainly by Rashaida nomads of eastern Sudan who migrated from Saudia Arabia relatively recently. Some Rashaidi camels are owned by tribes who share the same ecological zone such as Shukria, Bataheen and Lahaween tribes (Al-Amin, 1979). Rashaidi camels produce sufficient amounts of milk ranging from 2000 to 3000 kg/ head/ lactation (Wardeh, 1989, Kohler-Rollefson *et al*. 1990, and Al-Khouri, 2000).

2:4:2 Riding camels:

This is the type whose conformation is best suited for riding and is selected mainly for its speed. It is lighter in body weight, and characterized by small head and ears, long and fine shoulders, very deep chest and well muscled quarter. It is mainly bred in the north-east of the country between River Nile and red sea and includes the following types:

A. Anafi camel: The Anafi camel is the fastest subtype. It has long legs, white body colour, small hump and long narrow head. They are bred by Al-Rufaa, Kenana, Shukreya and Kawahla tribes.

B. Bishari camel: These camels are reared by Bisharin, Al-amarar, Hadandwa and Beni Amir in Kassala and Red Sea regions. They are very famous for their racing ability (Wardeh, 1989). These animals are stronger and slightly larger than Anafi type. Al-Khouri (2000) described the Bishari camel as having short and strong legs, fine and thin skin and white to yellow colour.

Various camel-owing nomadic groups have developed riding camels from crosses of Bishari or Anafi camel with their own local strain.

2:5 Camel management:

Management is concerned with principal factors, which have direct effect on production and reproduction. According to Gihad (1995) the management systems of camel depend on factors including: composition and size of the herd, environmental conditions, and the degree of reliance of herders on their camels.

Ismail and Mutairi (1991) studied the influence of improved management on production parameters. They revealed that the local camel breeds in Saudi Arabia are potentially meat and milk producers if management system is improved. Abdel-Rahim and Al-Nazeir (1990) reported that poor management and lack of feeding supplements during the breeding season are the main causes of unsatisfactory reproductive performance.

2:6 Camel's Production Systems:

For the nomads who inhabit the desert and semi desert regions in Sudan the camel plays important cultural, economic and social roles in the lives of these communities. In these marginal lands, stricken by recurrent droughts the camel is usually the sole survivor when all other types of livestock have succumbed. To those people camel herding is a way of life, an insurance against natural disaster and a highly valued cultural heritage. In Sudan three main types of management systems for camel herds are adopted. These are:

2:6:1 Traditional Nomadic System:

This system is dominant in the geographical zone between 13◦N to 16◦N (Northern part of the camel belt) (Al-Khouri and Majid, 2000). This is typically practiced by the Kababish tribe in Northern Kordofan State. The camel herders are continuously on the move in response to availability of grazing and water supplies.

2:6:2 Transhumant or Semi-Nomadic System:

This system is found in eastern and southern regions of the camel belt and is practiced by semi-nomadic tribes (Al-Khouri and Majid, 2000). In this system a degree of settlement is experienced during the rainy season where rainfed agriculture is practiced for stable food production and the crop residues provide feed supplement for camel populations (Bakheit, 1999).

Tribes in Eastern Sudan practice a transhumant mode of range utilization (Abbas *et al.* 1992). They move from one area to another following certain migratory routes. The Rashaida spend the rainy season (July - October) around Kassala and move about 400 Km to spend the dry season (March - June) in the southern fringes of their traditional zone in Doka area. Members of the Shukria, Lahaween and Kawahla tribes stay in Butana plains during the rainy season, either to the south (Gadaref) or to the southeast along the Atbra River course (Agab and Abbas, 1993).

2:6:3 Sedentary or Semi-sedentary System:

This system is practiced in the eastern region of Sudan (East of River Nile and west of the Red Sea hills). It is also practiced in the agricultural areas in the central and southern parts of the camel belt (Al-Khouri and Majid, 2000).

Bakheit (1999) stated that an intensive system of production exists but it is limited to racing and dairy camels.

The three camel production systems: nomadic, transhumant and sedentary are also found in Pakistan (Aujla *et al*., 1998). Camel production systems in Sudan are interchangeable depending on conditions in the particular season and location. Camel owners can

change from one system to another in response to financial, labor, climate, and investments factors.

2:7 Feeding:

Knoess (1977) stated that the most important feeding characteristic of the camel is its ability to utilize plants that grow well under arid conditions and not relished by other grazing animals. Camels obtain about 44% of their feeding requirements from natural grazing land over the whole year (Rees *et al.* 1988). Kohler-Rollefson *et al.* (1991) studied the pastoral camel production system of Rashaida tribe in Sudan. They revealed that dura (sorghum) stalks, which remained after mechanized harvesting, have become an important, nutritionally adequate type of fodder. In Ereteria, Gebrehiwet (1998) mentioned that camels live in desert and semi-desert regions browsing and grazing all year round without any supplementary feeding.

2:8 Watering:

The dromedary camel can endure more than 30% water loss from its body. Aujla *et al.* (1998) found in Pakistan that the water requirements of camels varied from season to season from 5 to 15 liters per day. Ramet (2001) concluded that where green forage is available in wild climates, the camel may go several months without drinking. Camels under hot conditions may drink only once every eight to ten days and lose up to 30% of its body weight through dehydration (Yagil, 1982 and Wilson, 1984). Koheler-Rollefson *et al.* (1991) in their study of Rashaida camel in Sudan found that camels required watering approximately once every six days.

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Chapter three

Characterization of production system of Sudanese camel breeds

Abstract:

The aim of this study was to attempt to illuminate the conditions under which camels are raised and to identify breeding goals of camel owners, husbandry practices and production constraints as an essential step towards the development of a sustainable breed improvement programme. A set of detailed structured questionnaires were used to collect information from camel breeding areas (Sinnar, Gadaref, Gezira and North Kordofan states). The camels are a major component of the agro-pastoral system and are the dominant livestock species in parts of those states. The majority of camel owners in Sinnar, Gedaref and North Kordofan states indicated livestock breeding to be their main activity, while camel owners in Gezira state considered that both livestock and crop farming were their main activity. Camels have multi-functional roles in different production systems. Sales of animals are important for obtaining regular cash income, in addition to sales of agricultural crops, while milk production is used only for home-consumption. The serious production constraints which were defined by camel owners include lack of feeds, disease prevalence and water shortage. The priority of camel owners for genetic improvement was for a dual purpose animal (meat and milk production) rather than a specialized animal. However, racing ability also received some consideration.

Key words: Production systems, camel, Sudan, characterization.

3:1 Introduction:

Camels are an important livestock species in the arid and semi-arid zones in Asia and Africa. Camels contribute significantly to the

livelihood of the pastoralists and agro-pastoralists living in the fragile environments of the deserts and semi deserts of Asia and Africa. The camel population in Sudan was estimated to be 3.908 millions heads (Ministry of Animal Resources, 2005). They are well adapted to the local environmental conditions and can survive in zones which are prohibitive for other livestock species. They occupy a geographical zone to the north of latitude 14ºN in the west and 16 ºN in the east (Wilson, 1984).

The camels of Sudan belong to the species *Camelus dromedarius*, and are owned and raised by nomadic tribes. Camel herders migrate north in the wet season and south during the dry season. Camels in the Sudan are classified as pack (heavy) and riding (light) types according to the function they perform. These traits were probably developed as a result of selection applied by the various camel owning tribes. The Sudanese heavy type camels constitute the majority of the camels kept by nomads in Sudan. Within this group two subtypes can be identified on the basis of conformation and tribal ownership: The Arab and Rashaidi camels. The Arab camel may be further subdivided into Light Pack, Big Arabi and Heavy Arabi. On the other hand, the riding camels are restricted to the north-east of the country between the Nile and Red Sea. The two main recognized riding types are Anafi and Red Sea Hills (Bishari) camels (El-Fadil, 1986).

The increasing human population pressure and declining per capita production of food in Africa precipitated an urgent need to develop previously marginal resources, such as the semi-arid and arid rangelands, and to optimize their utilization through appropriate livestock production systems among which camel production is

certainly the most suitable (Schwartz, 1992). Despite the camel's considerable contribution to food security in semi dry and dry zones, and its being a major component of the agro-pastoral systems in vast pastoral areas in Africa and Asia, little is known about its production potential and production systems compared to other domestic animals. However, most previous research conducted on camels was oriented towards diseases, reproductive physiology and characterization (Mehari *et al*., 2007). The available information on camel production potential and production systems especially in Sudan is inadequate.

This study was carried out in four regions of camel breeding in western, central and eastern Sudan, with the objective of clarifying the conditions of production systems and to identify breeding goals, husbandry practices and production constraints as an essential step towards the development of a sustainable breed improvement program.

3:2 Materials and methods:

3:2:1 Sampling and questionnaire methodology:

The survey was conducted through a questionnaire and guided interviews with camel owners in selected regions of the camel habitat. Four states were selected: Sinnar and Gezira states in central Sudan, Gedaref state in eastern Sudan and North Kordofan state in western Sudan.

A set of detailed structured questionnaires (Appendix 1) were prepared and used to collect information from a total of 103 camel owners in different states in interview conducted over two visits (Table 3.1). The questionnaires were pre-tested to check clarity and appropriateness of the questions. Some of the information collected during interviews was supported by observation. The questionnaires

were designed to obtain information on general household characteristics, livestock and herd structure, herd management, breeding practices, disease prevalence, production objectives, feeding management and production constraints.

Table 3.1: The regions selected for the survey

State	Regions	number of owners
Sinnar	Abu-hugar, Wad-Elnayal, Abu-Naama, Singa	24
Gezira	Tambol (Afasa, Zorga, Sayal)	13
Gedaref	Shuwak (Sharif Kabbashi, Um-gargoor)	37
North Kordofan	Obied, Dibeibat, Mazroob	29
Total		103

3:2:2 Data analysis:

The SPSS statistical computer software (SPSS for windows, release 15.0, 2006) was used to analyze the data. The analysis was implemented separately for camel owners of each state. Results are represented mainly in the form of descriptive tabular summaries. Chi-square, contingency table for independence was run for comparison between regions. Analysis of variance was also conducted for milk production and reproduction traits.

3:3 Results:

3:3:1 General household information:

Table (3.2) presents the education level of camel owners. The results revealed that 83.5% of camel owners were illiterate and 14.6% completed primary school, while only 1.9% of them were university graduates.

Table (3.3) shows the numbers and percentages of the different livestock species in the studied regions. Of the 103 camel owners

interviewed 11 (10.7%) owned only camels (4.2, 10.8, 23.1 and 10.3% of owners in Sinnar, Gedaref, Gezira and North Kordofan state). However, only one of the interviewees owned both camels and cattle (1% of the total). This case was in Sinnar state and it represented 4.2% of camel owners in that state. Of those who bred camels and sheep were 22 (21.4%), the highest number, was found in Gedaref (48.6%), followed by Gezira (7.7%) and North Kordofan (6.9%) and finally Sinnar (4.2%). Two of the interviewees, one in Gezira the other in North Kordofan owned camels and goats representing 1.9% of the total and 7.7% and 3.4% of interviewees in Gezira and North Kordofan, respectively. Three owned camel, cattle and sheep (2.9% of the total). They were found only in Sinnar (8.3%) and Gedaref (2.7%). Those who owned camel, sheep and goat were 37 (35.9%) found in Sinnar, Gadaref, Gezira and North Kordofan (20.8, 27.0, 23.1 and 65.5%, respectively). Only 27 (26.2%) of owners bred camel, cattle, sheep and goat (58.3%, 10.4%, 38.5% and 13.5% corresponding to Sinnar, Gedaref, Gezira and North Kordofan states, respectively). The chi-square test for independence was found to be significant (χ^2 =58.95, P < 0.001).

Table 3.2: Education level of camel owners

Regions	Level of education					
	Illiterate		Primary		Graduated	
	n	%	n	%	n	%
Sinnar	23	95.8	0	0.0	1	4.2
Gedaref	30	81.1	7	18.9	0	0.0
Gezira	7	53.8	6	46.2	0	0.0
Kordofan	26	89.7	2	6.9	1	3.4
Overall	86	83.5	15	14.6	2	1.9

Table 3.3: Livestock species in the studied regions

Livestock species	Sinnar		Gedaref		Gezira		Kordofan		Overall	
	n	%	N	%	N	%	n	%	n	%
Camel	1	4.2	4	10.8	3	23.1	3	10.3	11	10.7
Camel, cattle	1	4.2	0	0	0	0	0	0	1	1.0
Camel, sheep	1	4.2	18	48.6	1	7.7	2	6.9	22	21.4
Camel, goat	0	0	0	0	1	7.7	1	3.4	2	1.9
Camel, cattle, sheep	2	8.3	1	2.7	0	0	0	0	3	2.9
Camel, sheep, goat	5	20.8	10	27.0	3	23.1	19	65.5	37	35.9
Camel, cattle, sheep, goat	14	58.3	4	10.4	5	38.5	4	13.5	27	26.2

Table (3.4) shows the importance of livestock and crop farming in the surveyed regions. The majority of camel owners (61.2%) indicated that their main activity was livestock breeding, while 7.8% said it was farming and 31.1% had both livestock breeding and farming as the main activity. Of camel owners in Sinnar state 91.7%, 0% and 8.3% indicated that their main activities were livestock, farming, livestock and farming, respectively. The corresponding percentages are 51.4, 18.9 and 29.7 for camel owners in Gedaref, 38.5, 0 and 61.5 for those in Gezira, and 58.6, 3.4 and 37.9 for those of North Kordofan. Significant differences ($\chi^2 = 23.19$, $P > 0.001$) were found between regions in the main activities of interviewees.

Table 3.4: The importance of livestock and crop farming in surveyed areas

Regions	Main activities					
	Livestock		Farming		Livestock & farming	
	n	%	n	%	n	%
Sinnar	22	91.7	0	0.0	2	8.3
Gedaref	19	51.4	7	18.9	11	29.7
Gezira	5	38.5	0	0.0	8	61.5
Kordofan	17	58.6	1	3.4	11	37.9
Overall	63	61.2	8	7.8	32	31.1

Data in Table (3.5) shows the numbers and percentages of respondents who had grown and sold crops within the past 12 months. The questionnaire survey showed that 54.2, 64.9, 84.6 and 69.0% of respondents in Sinnar, Gedaref, Gezira and North Kordofan, respectively grew crops. The Chi-square test revealed insignificant (χ = 3.64, P > 0.05) differences between regions. Sorghum and Sesame were the main crops grown by respondents in Sinnar, Gedaref and Gezira states. However, camel owners in North Kordofan grew Groundnuts and Karkadae (*Hibiscus sabderifa*) in addition to Sorghum and Sesame. Only 38.5, 37.5, 63.6 and 45.0% of respondents in Sinnar, Gedaref, Gezira and North Kordofan, respectively reported that they sold crops within the past 12 months. The differences between regions in percentages of respondents who sold crops within the past 12 months were insignificant (χ^2 = 2.30, P > 0.05).

Table 3.5: Crop growing and selling in four regions within 12 months prior to time of survey

Regions	Crop growing				Crop sold			
	Yes		No		Yes		No	
	n	%	n	%	N	%	n	%
Sinnar	13	54.2	11	45.8	5	38.5	8	61.5
Gedaref	24	64.9	13	35.1	9	37.5	15	62.5
Gezira	11	84.6	2	15.4	7	63.6	4	36.4
Kordofan	20	69.0	9	31.0	9	45.0	11	55.0
Overall	68	66.0	35	34.0	30	44.1	38	55.9

3:3:2 Management systems and migrations during past year:

Camel management systems adopted by owners in studied areas are shown in Table (3.6). The majority of camel owners (69.9%) adopted a sedentary management system, 21.4% of owners adopted a nomadic system, while only 8.7% of them adopted a transhumant system. All camel owners in Gezira were sedentary, while 73.0, 66.7

and 55.2% of camel owners in Gedaref, Sinnar and North Kordofan adopted a sedentary system. Moreover, the results showed that the highest percentage of the nomadic system was found in North Kordofan (44.8%) and Sinnar (33.3%). On the other hand, the transhumant management system was found only in Gedaref (24.3%). Significant differences were reported between camel owners in the type of camel management system adopted ($\chi^2 = 36.20$, $P < 0.05$).

Table 3.6: Camel management system

Regions	Management system					
	Nomadic		Transhumant		Sedentary	
	N	%	n	%	n	%
Sinnar	8	33.3	0	0	16	66.7
Gedaref	1	2.7	9	24.3	27	73.0
Gezira	0	0	0	0	100.0	100.0
Kordofan	13	44.8	0	0	16	55.2
Overall	22	21.4	9	8.7	72	69.9

Table (3.7) showed camel migration during the past 12 months prior to the conduct of the survey in different regions. Most camel owners (93.2%) migrated with their animals during the last 12 months; in search of pasture and water and escaping from insects in the rainy season. In Gezira, all camel owners moved to the north in the wet season and returned to their original areas in the dry season. In North Kordofan and Gedaref states 82.8% and 97.3% of camel owners respectively migrated during the last year. Two migration modes were identified by camel owners in North Kordofan state. In the first mode or long distance migration, the camel owners (Maalia, Shanabella, Maganeen, Awamera and Maagela tribes) stayed in Southern Kordofan near Deleng and Kadogli towns in the dry season, and moved to the north in the wet season to the vicinity of Mazroob. In the second mode or short distance migration, the camel owners

(Maganeen, Dar-hamed, Kawahla, Hamar and Kababish tribes) stayed near Obeid city in the dry season, and moved in the wet season to the north around Gebel Alain. The camel owners in Gedaref state also had two patterns of migration. The first pattern is adopted by Rashaida tribes, whereby in the wet season (June to Nov.) they cross the Atbra River and move to the north near the New Halfa town and then return after the harvest of crops (Sorghum and Sesame) in the dry season and stay in vicinity of Shuwak town. The second pattern is adopted by Lahween tribes; who move to the north in the wet season but do not cross Atbra River and spend the season in Soubag area (north of the Butana plain). In Sinnar state 95.8% of camel owners migrated during the last 12 months. Those owners remain in the dry season (Nov. to June) in southern Sinnar state and north Blue Nile state; then they move to the northern approaches of Dweim town (White Nile state) in the wet season. Chi-square tests revealed insignificant differences between respondents in their migration during last 12 months (χ^2 = 7.18, P > 0.05).

Table 3.7: Camel migration in surveyed regions

Regions	Migrated		Not-migrated	
	n	%	n	%
Sinnar	23	95.8	1	4.2
Gedaref	36	97.3	1	2.7
Gezira	13	100.0	0	0
Kordofan	24	82.8	5	17.2
Overall	96	93.2	7	6.8

3:3:3 Livestock herd size and camel herd composition:

The livestock herd size in different regions is presented in Table (3.8). The results (analysis of variance) revealed that the regions have insignificant effect on the herd size of each species. The average

camel herd size in surveyed areas was 75.32 heads, the highest camel herd size was recoded in Gedaref state (81.92), followed by North Kordofan (69.24) then Sinnar (63.71); while the Gezira had the smallest camel herd size (62.31). The highest cattle herd size was recorded in Gedaref (115.80) while the smallest size recoded was in Gezira state (11.80). The average sheep flock size was found to be 157.82 heads. The largest flock size was recorded in Sinnar (207.00), followed by Gedaref (165.00) and Gezira (159.75). However, North Kordofan state recorded the lowest sheep flock size (96.75). The results revealed that the average goat flock size in studied areas was 46.47 heads, the highest flock size was found in Gedaref state (55.64), followed by North Kordofan (49.11), Sinnar (42.47), while camel owners in Gezira had the lowest goat flock size (33.00). Always the camel herd was managed or herded by two persons, the oldest one called (Alrayes) who is the main herder, while the youngest one called (Angeeb) who is an assistant.

Table 3.8: Livestock herd size in different camel regions

states / species	Sinnar		Gedaref		Gezira		Kordofan		Overall	
	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean
Camel	24	63.71	37	81.92	13	62.31	29	69.24	103	75.32
Cattle	14	25.50	5	115.80	5	11.80	4	87.50	28	48.04
Sheep	20	207.00	31	165.00	8	159.75	20	96.75	79	157.82
Goat	17	42.47	14	55.64	8	33.00	18	49.11	57	46.47

The camel herd composition in surveyed regions is shown in Table (3.9). The percentage of she-camels in this study ranged between 41.9% in Sinnar state to 50.0% in Gezira state. The percentage of mature males ranged between 2.3% in Gezira to 3.8% in North Kordofan. Generally the female camels contribute about 74% of the total herd size. The young male and female calves (< 1 year) have

almost similar percentages (8.2 and 8.5%, respectively). The percentage of growing females (< 4 years) was greater than the percentage of growing males. Castrated animals were found only in North Kordofan state. The analysis of variance showed that region had insignificant influence on herd composition.

Table 3.9: Camel herd composition in different regions

States / Item	Sinnar		Gedaref		Gezira		Kordofan		Overall	
	No	%	No	%	No	%	No	%	No	%
Mature females	26.7	41.9	37.7	46.0	31.2	50.0	32.5	47.0	32.8	45.8
Females <4	13.6	21.4	16.5	20.1	13.2	21.2	12.2	17.6	14.2	19.8
Females <1	6.8	10.7	7.1	8.7	2.9	4.6	5.7	8.2	6.1	8.5
Mature males	1.8	2.8	2.0	2.4	2.3	3.7	2.6	3.8	2.2	3.1
Males <4	8.8	13.8	11.7	14.3	9.2	14.7	10.6	15.3	10.4	14.5
Males <1	6.0	9.4	7.0	8.5	3.6	5.8	5.5	7.9	5.9	8.2
Castrated males	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0

3:3:4 Camels sold, bought and died:

Numbers and percentages of camel owners who sold and bought camels are presented in Table (3.10), while, the numbers of camels sold and bought are reported in Table (3.11). Fifty percent of camel owners in Sinnar state sold animals within the 12 months preceeding the survey period, while; 78.4, 69.2 and 75.9% of camel owners in Gedaref, Gezira and North Kordofan states respectively sold camels in the same period. The highest number of sold animals were recoded in Gedaref state (7.90), followed by Sinnar (5.33), North Kordofan (4.41), while the lowest number was recorded in Gezira state (4.00). The camels were sold for various reasons; In Gedaref state the camels were sold in order to buy sorghum residues after harvesting (straw), pay taxes and to cover family needs. The reasons in Gezira were to

solve agricultural financial problems, pay taxes, cover family needs, buy breeding females (after selling male camels) and buy sorghum residues. In addition to the previous reasons, treating of animals and covering cost of camel herder were reported in Sinnar state. Figure 3.1 shows the sources of income and costs of camel owners. Chi-square test revealed insignificant differences between camel owners who sold or bought camels within the past year.

Table 3.10: Percentages of camel owners who sold or bought camels within the past 12 months

Regions	Camel sold				Camel bought			
	Yes		No		Yes		No	
	N	%	n	%	N	%	N	%
Sinnar	12	50.0	12	50.0	2	8.3	22	91.7
Gedaref	29	78.4	8	21.6	7	18.9	30	81.1
Gezira	9	69.2	4	30.8	3	23.1	10	76.9
Kordofan	22	75.9	7	24.1	3	10.3	26	89.7
Overall	72	69.9	31	30.1	15	14.6	88	85.4

Table 3.11: Numbers of sold and bought animals

	Sinnar	Gedaref	Gezira	Kordofan
Sold animals:				
Both sexes	5.33	7.90	4.00	4.41
Males	2.42	4.21	1.78	2.45
Females	2.92	3.69	2.22	1.95
Bought Animals:				
Both sexes	1.50	5.00	1.67	7.00
Males	0.00	0.83	0.33	0.00
Females	1.50	4.17	1.33	7.00

The majority of camel owners (85.4%) did not buy animals within the last 12 months preceding the survey period. The percentages of camel owners who bought animals in Sinnar, Gedaref, Gezira and North Kordofan states were 8.3, 18.9, 23.1 and 10.3%, respectively. The largest number of animals bought was in North Kordofan (7.0) followed by Gedaref (5.0), while the smallest numbers

were recorded in Gezira (1.67) and Sinnar (1.50). Generally, breeding purposes was the main reason for buying camels in all the studied areas (numbers of female camels bought more than males). Insignificant differences were found in numbers of camel sold or bought between regions.

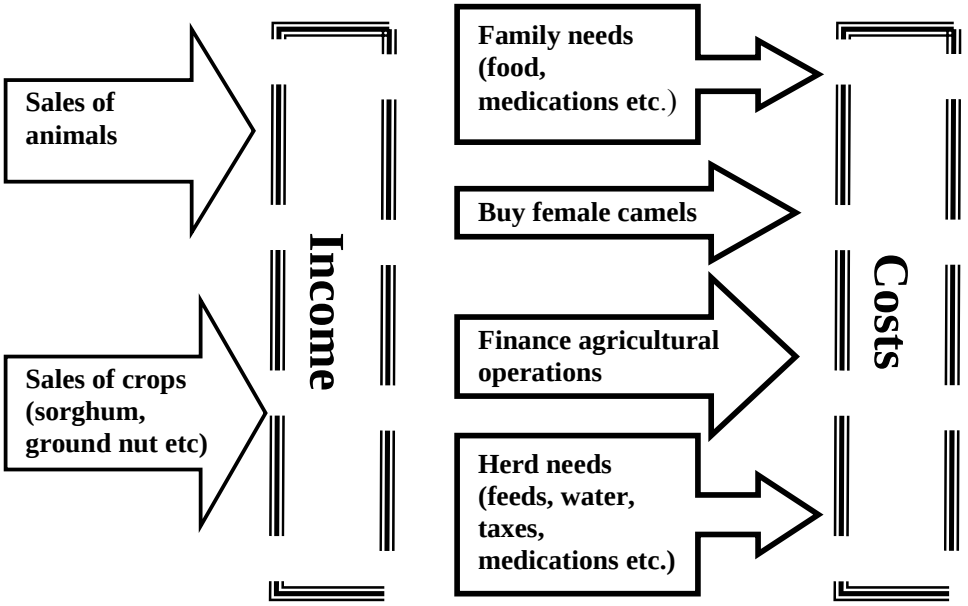

Fig 3.1: Sources of income and costs for camel owners (cash flow)

The results showed that 52.4% of respondents reported that some of their camels died within the last 12 months (Table 3.12). The highest percentage of them was found in Sinnar state (70.8%) followed by Gezira (53.8%) Gedaref (51.4%), while the lowest percentage recorded was in North Kordofan state (37.9%). Regarding the number of dead camels, the Gedaref state ranked first with 5.06 animals, followed by Sinnar (4.41) then North Kordofan (3.64), while, the lowest percentage was found in Gezira state (3.43). Chi-square tests revealed insignificant differences between numbers of interviewees who had dead camels in the surveyed regions ($\chi^2 = 5.73$,

P > 0.05). Diarrhea of young calves (1-12 months) was the main cause of losses in camel herds in the studied areas. However, other diseases e.g. trypanosomiasis, internal worms, bloat and pneumonia were also important. Fractures, wounds and snake bites were also reported in different regions as a common factor in camel losses.

Table 3.12: Percentages of camel owners having dead camels within 12 months and numbers of dead camel

Regions	Incidence of camel death				No. of dead camel		
	Yes		No				
	n	%	n	%	Males	Females	All
Sinnar	17	70.8	7	29.2	1.65	2.76	4.41
Gedaref	19	51.4	18	48.6	2.33	2.72	5.06
Gezira	7	53.8	6	46.2	2.00	1.43	3.43
Kordofan	11	37.9	18	62.1	1.73	1.91	3.64
Overall	54	52.4	49	47.6	1.94	2.40	4.34

3:3:5 Breeding practices:

The majority of camel owners (94.2%) kept breeding male camels (Table 3.13). All camel owners in Gezira state had breeding camels, while 91.7% of camel owners in Sinnar state kept breeding camels. Chi-square tests indicated insignificant differences between the numbers of camel owners who kept breeding camels in the studied regions. The results also revealed that the average number of breeding camels was 1.55 camels per herd, the largest number was found in Gezira state (1.69), followed by North Kordofan (1.67) then Gedaref (1.49), while the lowest percentage (1.41) was recorded in Sinnar state (Table 3.13). Camel owners who did not keep breeding camels reported the small size of herd and death of breeding camel as the main reasons for absence of a breeding camel. Two breeding seasons were identified in the surveyed regions: One in autumn (July - Oct.)

and the other in winter (Nov. - Feb.). In herds with two breeding camels, the first was activated in the autumn breeding season and the other was used in the winter breeding season. The majority of breeding camels belonged to the pack type (Arabi camel and Rashaidi). However, in Gedaref, Gezira and Sinnar states breeding camels belonged to the riding type (Anafi and Bishari) were also observed.

Table 3.13: Percentages of camel owners keeping breeding camel and numbers of breeding camels

Regions	Keeping of Breeding camel				No. of breeding camels		
	Yes		No		Minimum	Maximum	mean
	n	%	n	%			
Sinnar	22	91.7	2	8.3	1	3	1.41
Gedaref	35	94.6	2	5.4	1	5	1.49
Gezira	13	100.0	0	0.0	1	3	1.69
Kordofan	27	93.1	2	6.9	1	4	1.67
Overall	97	94.2	6	5.8	1	5	1.55

Table (3.14) shows the sources of breeding camels and ages of selection and keeping. 82.5% of camel owners reported that the source of breeding camels was their own herds, 3.1% said the breeding camel was from another herd and 14.4% purchased the breeding camel from the market. The results showed that the average age of selection was 3.19 years, the a significantly younger age of selection (2.57 years) was recorded in Gedaref state, followed by North Kordofan (3.04) then Gezira (3.20). A significantly older age of selection was found in Sinnar state (4.14 years). Also, the results (Table 3.14) showed that the average age of keeping breeding camels in the herd in the surveyed areas was 15.33 years. A significantly lower age was reported in Gedaref (13.88), and a significantly higher age of keeping was found

in the Gezira state (18.08). The interviewees reported that the age of sexual maturity of breeding camels ranged between 6 and 8 years.

Table 3.14: Source of breeding camels, age of selection and age at end of herd life

Regions	Sources of breeding camel						Ages of	
	Own herd		Other herd		Purchased		Selection	keeping
	n	%	n	%	n	%	years	years
Sinnar	19	86.4	0	0.0	3	13.6	4.14[b]	17.38b
Gedaref	25	71.4	3	8.6	7	20.0	2.57a	13.88a
Gezira	11	84.6	0	0.0	2	15.4	3.20ab	18.08b
Kordofan	25	92.6	0	0.0	2	7.4	3.04ab	13.93a
Overall	80	82.5	3	3.1	14	14.4	3.19	15.31

a,b means with the same letters were insignificantly ($P < 0.05$) different.

The results in Table (3.15) showed that 49.5% of camel owners sold male camels that were not selected for breeding purposes, 14.1% of owners sold males as castrate camels. Only 1.0% of males were left in the herd, while 35.4% were camels used for various purposes such as packing, drought power and riding. However, the differences between regions were significant ($\chi^2 = 26.25$, $P < 0.01$).

Table 3.15: The fate of male camels not selected for breeding purposes

Regions	Castrate		Kept in herd		Sold		Other	
	n	%	n	%	n	%	n	%
Sinnar	8	33.3	0	0.0	10	41.7	6	25.0
Gedaref	0	0.0	0	0.0	19	54.3	16	45.7
Gezira	0	0.0	1	7.7	5	38.5	7	53.8
Kordofan	6	22.2	0	0.0	15	55.6	6	22.2
Overall	14	14.1	1	1.0	49	49.5	35	35.4

Table (3.16) shows the source of replacement breeding camels. The majority of camel owners (91%) reported that they select replacement breeding camel from own herd, 5% of owners selected them from other herds, while only 4% of owners purchased replacement breeding camels from markets. 96.9% of interviewees

explained that they select the son of former breeding camel to become the new replacement breeding camel. Dam reproduction and milk performance, sire performance, body size, conformation of animal selected, grazing behavior, health and vigor were the most important characteristics for camel owners when selecting breeding camels of pack types (Arabi and Rashaidi camel). However, dam and sire performance, shape of animal selected and racing ability were the most important properties for camel owners when selecting breeding camels of the riding types (Anafi and Bishari).

Table 3.16: Source of replacement of breeding camel

Regions	Source of replacement breeding camel						Son of former breeding camel			
	Own herd		Other herd		Purchased		Yes		No	
	N	%	n	%	n	%	n	%	n	%
Sinnar	22	91.7	2	8.3	0	0.0	23	100.0	0	0.0
Gedaref	31	88.6	2	5.7	2	5.7	32	91.4	3	8.6
Gezira	13	100.0	0	0.0	0	0.0	13	100.0	0	0.0
Kordofan	25	89.3	1	3.6	2	7.1	27	100.0	0	0.0
Overall	91	91.0	5	5.0	4	4.0	95	96.9	3	3.1

The goals of camel improvement were presented in Table (3.17). The study showed that the improvement of camel for milk and meat production ranked first (47.6% of respondents), followed by improvement for meat (27.2%) and for milk and racing (12.6%). The improvement of camels for racing only ranked last at 1.0%. The majority of camel owners in Sinnar and North Kordofan (75.9 and 54.2%, respectively) improved their camels for meat and milk production. In Gezira state 61.5% of interviewees improved their camels for milk and racing. Gedaref state camel owners improved their camels for meat production (37.8%), and for both milk and meat

(32.4%). Significant differences were found between respondents of surveyed regions in goals of camel improvement ($\chi^2 = 74.64$, $P < 0.01$).

Table 3.17: Goals of camel improvement

Regions	Goals of improving camels											
	Milk		Meat		Racing		Milk, meat		Milk, racing		Meat, racing	
	N	%	n	%	n	%	N	%	n	%	n	%
Sinnar	0	0.0	7	29.2	0	0.0	13	54.2	0	0.0	4	16.7
Gedaref	6	16.2	14	37.8	0	0.0	12	32.4	5	13.5	0	0.0
Gezira	0	0.0	0	0.0	1	7.7	2	15.4	8	61.5	2	15.4
Kordofan	0	0.0	7	24.1	0	0.0	22	75.9	0	0.0	0	0.0
Overall	6	5.8	28	27.2	1	1.0	49	47.6	13	12.6	6	5.8

All camel owners in Sinnar and North Kordofan state stated that they have plans to improve their camels. In Gedaref and Gezira states 91.9 and 92.3% of camel owners have plans to improve camels' performance (Table 3.18). 50.5% of respondents reported that they improve camel production by selection of the best breeding camel, 3.0% of them improve camels by feeding, while 46.5% of them improve their camels by selection and feeding together.

Table 3.18: Percentage of camel owners having plans for camel improvement and method of improvement

Regions	Have plan				Method of improvement					
	Yes		No		Selection		feeding		Selection and feeding	
	n	%	n	%	n	%	n	%	n	%
Sinnar	24	100.0	0	0.0	21	87.5	0	0.0	3	12.5
Gedaref	34	91.9	3	8.1	15	44.1	0	0.0	19	55.9
Gezira	12	92.3	1	7.7	7	58.3	0	0.0	5	41.7
Kordofan	29	100.0	0	0.0	7	24.1	3	10.3	19	65.5
Overall	99	96.1	4	3.9	50	50.5	3	3.0	46	46.5

3:3:6 Milk production and reproductive performance:

Milk production performance is outlined in Table (3.19). The results showed that the average milk yield was 1557 ± 672 liter /

lactation, camels of Gedaref states produced insignificantly more milk (1656 liter), followed by Gezira (1515) then Sinnar (1508) while North Kordofan she-camels produced an insignificantly lower amount of milk (1489). The camel owners reported that camels produced the highest milk yield in autumn because of the abundance of lush pastures and sufficient water. Rashaidi tribe milked their camels twice a day. However, other tribal groups milked their camels 3-4 times a day. The results of this study showed that the average lactation length in Sudanese camels was 11.48 months, the camels of Sinnar state lactated a significantly shorter period (10.54) than those of Gedaref, Gezira and North Kordofan states.

Table 3.19: Milk production performance of camels breeds of Sudan

Regions	Milk production (liter)				Lactation length (month)
	Beginning	Middle	End	Total	
Sinnar	7.38±2.19[a]	4.63±1.37[a]	2.18±0.84[a]	1508±533[a]	10.54±1.64[a]
Gedaref	7.10±2.57[a]	4.70±2.96[a]	2.22±1.15[a]	1656±756[a]	11.78±0.63[b]
Gezira	6.39±1.94[a]	4.12±1.42[a]	2.38±0.87[a]	1515±465[a]	11.77±0.60[b]
Kordofan	5.83±2.84[a]	4.17±2.19[a]	2.86±2.11[a]	1489±750[a]	11.72±0.84[b]
Overall	6.72±2.54	4.63±2.27	2.41±1.42	1557±672	11.48±1.12

a,b means with the same letters were insignificantly (P > 0.05) different.

Statistics of reproduction traits of camels are given in Table (3.20). The results revealed that the age at first calving and calving interval were significantly (P < 0.01) influenced by regions, but the number of services per conception and age for keeping she-camels in the herd were not affected. Also, the results revealed that the average age at first calving of she-camels was 4.87 ± 0.79 years. Significantly lower ages at first calving were found in North Kordofan (4.57 years) and Gedaref state (4.77 years), while significantly higher ages were recorded for camels of Sinnar state (5.18 years) and Gezira state (5.27

years). The averages of calving interval and number of services per conception were 23.09 ± 2.20 months and 1.63 services, respectively. The she-camels of Gezira state had significantly shorter calving intervals than those of other states. On the other hand, the highest but insignificant number of services per conception was recorded in she-camels of North Kordofan state, while, the lowest value was found in she-camels of Gezira state. The results also showed that the age of keeping she-camels ranged from 15.76 years in North Kordofan state to 18.43 years in Gedaref state with an average of 17.20 ± 4.24 years.

Table 3.20: Reproduction performance (mean ± SE) of camel breeds

Regions	Age at first calving (years)	Calving interval (months)	No. of services per conception	Age keeping she camel (years)
Sinnar	5.18 ± 1.05^{bc}	20.83 ± 2.88^{a}	1.56 ± 0.31^{a}	16.71 ± 4.56^{a}
Gedaref	4.77 ± 0.56^{ab}	23.59 ± 1.28^{b}	1.58 ± 0.46^{a}	18.43 ± 3.84^{a}
Gezira	5.27 ± 0.60^{c}	24.00 ± 0.00^{b}	1.54 ± 0.78^{a}	17.85 ± 5.41^{a}
Kordofan	4.57 ± 0.65^{a}	23.90 ± 1.70^{b}	1.79 ± 0.68^{a}	15.76 ± 3.51^{a}
Overall	4.87 ± 0.79	23.09 ± 2.20	1.63 ± 0.55	17.20 ± 4.24

a,b,c means with the same letters were insignificantly (P > 0.05) different.

Table 3.21: Production objectives of camel keeping

Regions	Drought		Low cost		Way of life		Save money		Social	
	N	%	n	%	n	%	n	%	n	%
Sinnar	8	33.3	7	29.2	7	29.2	2	8.3	0	0.0
Gedaref	1	2.7	3	8.1	30	81.1	0	0.0	3	8.1
Gezira	0	0.0	0	0.0	9	69.2	0	0.0	4	30.8
Kordofan	5	17.2	9	31.0	12	41.4	1	3.4	2	6.9
Overall	14	13.6	19	18.4	58	56.3	3	2.9	9	8.7

3:3:7 Purposes of keeping camels:

Table (3.21) shows production purposes of camel keeping. 56.3% of interviewees said that the keeping of camels is a way of life; 18.4% of them said they keep camels because they cost little and their

revenues are high; 13.6% reported that they keep camels because they are drought tolerant and perform well in extremely dry years. However, 2.9% of interviewees reported that they kept camel as a reservoir of wealth. Chi-square test observed significant differences between interviewees of surveyed areas in objectives of camel keeping ($\chi^2 = 42.75$, $P < 0.001$). Income from sale of animals, milk for home consumption, insurance against financial crises and investment opportunity were also reported as reasons of camel keeping.

3:3:8 Feeding and watering:

The majority of camel owners (81.6 and 82.5%) considered that the feeding and water supply respectively were important constraints to their herd production (Table 3.22). All Gezira state camel owners stated that feeding and watering were important constraints, while only 48.3% of camel owners in North Kordofan state considered that feeding was a constraint. Significant differences were found between camel owners of studied regions who considered that feeding was a constraint to herd production and those who disagreed ($\chi^2 = 30.95$, $P < 0.001$), but there were no significant differences between camel owners in considering water supply as a constraint ($\chi^2 = 6.89$, $P > 0.05$). The camels depend mainly on grazing and browsing, but in Gedaref and Gezira the weak animals were fed concentrates (Sorghum grains and cakes) in the dry season. Minerals (salt) were commonly used as a nutritional additive in surveyed areas.

The duration between every two consecutive watering times and distances between water points and grazing areas are shown in Table (3.23). The duration between every two waterings ranged between 3.8 and 7.0 days in the summer season. The duration between waterings is very variable in the winter and autumn seasons among the studied

areas. The significantly shortest durations were found in Gedaref state, while, the significantly longest periods were found in North Kordofan state. Also results showed the great variability in distances between water points and grazing areas in different seasons. However, the differences in distances between studied areas were not significant (P > 0.05). The sources of drinking water for camels were wells and ponds in all studied regions, while rivers were a source only in Sinnar and Gedaref states.

Table 3.22: Feeding and water supply

Regions	Feed is a constraint				Watering is a constraint			
	Yes		No		Yes		No	
	n	%	n	%	n	%	n	%
Sinnar	21	87.5	3	12.5	18	75.0	6	25.0
Gedaref	36	97.3	1	2.7	33	89.2	4	10.8
Gezira	13	100.0	0	0.0	13	100.0	0	0.0
Kordofan	14	48.3	15	51.7	21	72.4	8	27.6
Overall	84	81.6	19	18.4	85	82.5	18	17.5

Table 3.23: Duration between every two watering times and distance between water points and grazing areas

Items		Sinnar	Gedaref	Gezira	Kordofan
Duration (day)	Autumn	26.6^{a}	8.7^{a}	30.0^{a}	30.0^{a}
	Winter	7.9^{b}	5.3^{a}	7.5^{b}	19.9^{c}
	Summer	4.9^{b}	3.8^{a}	5.0^{b}	7.0^{c}
Distance (km)	Autumn	9.6^{a}	9.2^{a}	4.5^{a}	9.0^{a}
	Winter	26.1^{a}	27.9^{a}	24.3^{a}	23.3^{a}
	Summer	29.0^{a}	27.4^{a}	24.3^{a}	21.1^{a}

a,b means with the same letters were insignificantly (P > 0.05) different.

Data revealed that only 48.5, 72.8 and 57.3% of respondents had access to free water supply for their animals in summer, autumn and winter seasons. The highest percentage of respondents who had free access to water supply were found in Sinnar, followed by Gadaref and North Kordofan states, respectively. The lowest percentage was

recorded in Gezira state (Table 3.24). Trees, shrubs, grasses and herbs which were browsed or grazed by camels are showed in Appendices 2 and 3.

Table 3.24: Percentages of camel owners had free charge or paid of water supply

Regions	Seasons					
	Summer		Autumn		Winter	
	Free	Paid	Free	Paid	Free	Paid
Sinnar	87.5	12.5	87.5	12.5	91.7	8.3
Gedaref	51.4	48.6	81.1	18.9	67.6	32.4
Gezira	0.0	100.0	7.7	92.3	0.0	100.0
Kordofan	34.5	65.5	79.3	20.7	41.4	58.6
Overall	48.5	51.5	72.8	27.2	57.3	42.7

3:3:9 Animal health and camel production constraints:

Data of Table 3.25 shows the incidence of diseases during the past 12 months and sources of veterinary help available. 68.9% of respondents reported the incidence of diseases within the 12 months preceding the survey. The highest percentage was reported by respondents of Sinnar state (79.2%) followed by those of Gezira (69.2%), Gedaref state (67.2%), while the lowest percentage was reported by respondents of North kordofan (62.1%). Insignificant differences were observed between respondents of studied regions in disease incidence ($\chi = 1.84$, $P > 0.05$). Also results revealed that the majority of camel owners (78.6%) in surveyed areas found veterinary help from drug suppliers, while 11.7% found help from private services, and only 4.9% of them found the veterinary help from government services (Table 3.25). Insignificant differences were found between respondents of studied regions in disease incidence ($\chi^2 = 14.12$, $P > 0.05$).

Table 3.25: reports of diseases during preceding 12 months and sources of veterinary services

Regions	Report any disease during past 12 month				Veterinary help from							
	Yes		No		Government services		Private services		Drug suppliers		Others	
	n	%	n	%	n	%	n	%	n	%	n	%
Sinnar	19	79.2	5	20.8	0	0.0	3	12.5	21	87.5	0	0.0
Gedaref	25	67.6	12	32.4	0	0.0	6	16.2	30	81.1	1	2.7
Gezira	9	69.2	4	30.8	2	15.4	0	0.0	10	76.9	1	7.7
Kordofan	18	62.1	11	37.9	3	10.3	3	10.3	20	69.0	3	10.3
Overall	71	68.9	32	31.1	5	4.9	12	11.7	81	78.6	5	4.9

Important diseases in studied regions are shown in Table (3.26). Mange, ring worms, pneumonia, trypanosomiasis, anthrax, external parasites (ticks and lice), internal parasites (worms) and calf's diarrhea were prevalent diseases in the studied areas. Trypanosomosis was reported as the most important disease by 91.7% of camel owners in Sinnar state, 70.3% in Gedaref and 31.0% in North Kordofan state. In contrast camel owners in Gezira state reported that the mange was the most important disease. Chi-square tests showed significant differences between camel owners for important diseases reported ($\chi^2 = 96.55$, $P < 0.001$).

Production constraints which were defined by camel owners are presented in Table (3.27). Lack of livestock feed was mentioned as the most important constraint by most of the camel owners in Gedaref (91.9%), Gezira (92.3) and North Kordofan (58.6%), while only 20.8% of camel owners in Sinnar mentioned the lack of feeds as a constraint. Disease was the second most important constraint, but it ranked as the most important constraint in Sinnar state. Water shortage was also considered as a constraint by camel owners in Sinnar (4.2%) and North Kordofan (24.1%). A small portion of camel owners in the

surveyed areas mentioned that labour, capital, taxes and lack of security were important constraints. Chi-square tests showed significant differences between interviewees in their choice of serious constraints which influence camel production in surveyed areas (χ^2 = 79.01, P < 0.001).

Table 3.26: Important camel diseases in studied areas

Diseases	States							
	Sinnar		Gedaref		Gezira		Kordofan	
	n	%	n	%	n	%	n	%
Contagious skin necrosis	1	4.2	0	0.0	0	0.0	0	0.0
Calf Diarrhea	0	0.0	1	2.7	0	0.0	2	6.9
Dermatomycosis	0	0.0	1	2.7	0	0.0	1	3.4
Wry neck syndrome	0	0.0	3	8.1	0	0.0	3	10.3
Mange	1	4.2	2	5.4	11	84.6	2	6.9
Pneumonia	0	0.0	1	2.7	1	7.7	5	17.2
Anthrax	0	0.0	2	5.4	0	0.0	0	0.0
Ticks	0	0.0	0	0.0	0	0.0	1	3.4
Trypanosomiasis	22	91.7	26	70.3	0	0.0	9	31.0
Internal parasites	0	0.0	1	2.7	1	7.7	6	20.7

Table 3.27: Serious constraints to camel production

Serious constraint	Sinnar		Gedaref		Gezira		Kordofan		Overall	
	n	%	n	%	n	%	n	%	n	%
Diseases prevalence	13	54.2	0	0.0	0	0.0	2	6.9	15	14.6
Lack of feeding	5	20.8	34	91.9	12	92.3	17	58.6	68	66.0
Shortage of water	1	4.2	0	0.0	0	0.0	7	24.1	8	7.8
Labour	2	8.3	1	2.7	0	0.0	0	0.0	3	2.9
Capital	2	8.3	0	0.0	1	7.7	0	0.0	3	2.9
Taxes	0	0.0	2	5.4	0	0.0	0	0.0	2	1.9
Lack of security	1	4.2	0	0.0	0	0.0	3	10.3	4	3.9

3:4 Discussion:

Camels are a major component of the agro-pastoral systems in arid and semi arid zones, in addition to other species (sheep, goat and cattle). In the northern part of the camel belt in Sudan the annual rainfall is relatively low (semi desert) and limited cultivation is practiced to meet all or part of the family requirements, while in the southern part of the camel's belt the annual rainfall is relatively moderate (poor savannah).

This study revealed that the interviewees bred mixed species of animals in surveyed areas. Only 10.7% of them bred only camel, while the majority (35.9%) bred camel with sheep and goat. The highest percentage of camel owners who bred camel, sheep and goat were found in North Kordofan state because the environment in this region is very harsh and more suitable for these animals rather than cattle. The variety of species raised allows for optimum use of the available scant vegetation. Sheep and goats thrive in years of good rainfall while camels are the mainstay in years of poor or below average rainfall. The highest percentage of respondents owning cattle was found in Sinnar state; this region is the homeland of Kenana cattle, and is located in the southern part of the camel's belt. It is rich in vegetation and suitable for cattle breeding. The study showed that 61.2% of camel owners considered livestock raising to be their main activity, 31.1% considered both livestock and farming as their main activity, while only 7.8% of them said that farming was their main activity. On the other hand; 66% of camel owners cultivated crops during the 12 months preceding the conduct of the survey, and 44.1% of them sold crops in the same period. The shortage of rainfall might be the reason behind the small percentage of camel owners who sold

crops. These findings indicate that camels are kept in a mixed crop-livestock production system and that they are the most important component of the agro-pastoralist system in Sudan.

Three camel production systems were found in the studied areas of Sudan: Nomadic, transhumant and sedentary system. The nomadic system was the system adopted by 21.4% of respondents and those were mainly found in Sinnar (33.3%) and North Kordofan state (44.8%). Al-Khouri and Majid, (2000) explained that the nomadic system was dominant in the geographical zone between 13-16◦ N (Northern part of the camel's belt). Only 8.7% of camel owners adopted a semi-nomadic or transhumant system, and those were exclusively found in Gedaref state (eastern Sudan). This finding is in agreement with the reports of Al-Khouri and Majid, 2000; Bakheit, 1999 and Abbas *et al*., 1992. The majority of camel owners in this study (69.9%) adopted a sedentary management system, and most of them were observed in Gezira, Gedaref and Sinnar states. Al-Khouri and Majid, (2000) stated that the sedentary system was practiced in agricultural areas in the middle and south of the camel belt. These three management systems were also reported in Pakistan (Aujla *et al*., 1998). The results of this study revealed that 93.2% of respondents migrated with their herds during the past year in response to availability of grazing and water supplies and escaping from insects. Similar findings were also reported by Al-Khouri and Majid, 2000; Wardeh, 1989; Abbas *et al.* 1992 and Agab and Abbas, 1993.

The average camel herd size in this study was found to be 75.32 heads. This finding is reasonably close to that reported by Ali, (1998) for Sudanese camels in the Butana plain, but it is higher than that reported by Koheler-Roollefson *et al* (1991) for Rashaida camel in

Eastern Sudan; and lower than that reported by Djelloli and Saint Martin (1991) in Tunisia. The female camels contribute about 74% of the total herd size. This result is similar to that reported for camel herds in the Butana plain in Sudan (Ali, 1998). It is also similar to that reported for Tuarig herds in northern Mali. However, it is higher than that recorded for Kenya Rendille and Gabbra herds (Wilson, 1984). Where mature females contribute 45.8% of total herd size; this value was relatively smaller than that recoded in Sudan (Ali, 1998) and Suadia Arabia (Algayli et al., 1998). The percentage of breeding camels in this study was similar to that observed by Algayli *et al.* (1998) in Saudia Arbia. Differences in camel herd size and herd structure are probably a reflection of the differences between regions in the availability of feed and water. They may also reflect the degree of development of local markets and the extent to which camel production has developed into an economic venture rather than a way of life.

The results showed that 69.9% of respondents sold camels during the 12 months preceding survey time. The highest percentage of respondents who sold camels was observed in Gedaref state because the Rashadi tribe members in this state always sell growing males in contrast with other tribal groups who keep male camels for longer periods. The Rashadi herders are involved in brisk cross border trade with neighbouring countries and that makes them more sensitive to market demand and more likely to sell and buy animals. Only 14.6% of respondents bought camels during past year, the majority of camels bought being females for breeding purposes, herd replacement and to build up herd size. The results also showed that 52.4% of interviewees reported camel death during the past 12 months. The

highest percentage of reported deaths was in Sinnar state, while the highest absolute number of camels lost was reported in Gedaref state. The excessively high numbers of reported deaths in these two regions are related to the prevalence of serious diseases such as Trypanosomiasis and calf diarrhea.

There was a total lack of a recording system in all studied areas. None of the interviewees reported that he recorded the performance or health status of his herd. The influence of the high cost of keeping a male breeding camel in a small herd was observed in this study. The selection of breeding camels at a young age before maturity was also noted. The technique by which the Rashaidi tribe in Gedaref state prevent the increase of inbreeding was by shortening the herd life of the male breeding camels and in this manner prevent sires from serving their daughters. The majority of respondents selected the replacement male breeding camels from their own herd and they also select the sons of former breeding camels.

The lactation length in this study is in close agreement with the previous findings of Mehari *et al.* (2007) and that of Farah (1996) who reported a length of 9 to 18 months. However, the estimate of lactation length in this study is shorter than that reported by Schwartz and Walsh (1992) who indicated that the lactation length was 15 to 18 months. A shorter lactation length than the estimate found in the present study was also reported by Alemayehu (2001), in a study of Afar and Kereyu camels of Ethiopia he found a lactation length of 6 to 8 months in the two breeds, respectively. The milking frequency in the present study ranged between 2 to 4 times a day. This finding is in reasonable agreement with the finding of Mehari *et al.* (2007). The estimated mean daily milk yield during the early stage of lactation in

this study was similar to that reported by Mehari *et al.* (2007) for Babilie camels, while the estimated daily milk yield during middle and end of lactation were lower than that reported by Mehari *et al.* (2007) for Babilie and Kebribeyah camels. The estimated average total milk production in this study was found to be 1557 liter / lactation. This finding was similar to the findings of El-Amin, (1979) and Wilson, (1978) who reported that the total lactation production of Sudanese camels ranged between 1200 and 2600 kg. However, this finding is lower than that reported by Ismail and Al-mutairi (1990).

The average age at first calving in the present study was younger than that reported by Abdalla (1988). The average calving interval estimated in this study is similar to the finding of Bhattachraharya (1988) of 25 months for she-camels in Saudia Arabia. The average age of keeping she-camels was found to be 17.20 years in the present study. This is similar to the finding reported by Algayli *et al.* (1998) who stated that 75% of camel owners in Saudia Arabia said that the productive age of she-camels ranged between 16 and 20 years.

Results of this study showed that the majority of respondents improved their camels for both meat and milk production. These findings are not different from the findings of Algayli *et al.* (1998) who reported that 85% of camel owners in Suadia Arabia kept camels for milk and meat production. The majority of camels in the Sudan (90%) belong to the pack type (Arabi and Rashaidi camels), the Arabi camel has a wide geographic distribution in the Sudan due to its good performance for meat and milk. Wardeh (2004) in his new classification of camels placed the Arabi camel in the class of dual purpose animals (meat and dairy production). In this study, most

camel owners had plans to improve their camels' production but this planned improvement did not have any scientific basis.

The statement that camel raising was a way of life was the manner in which most owners explained the purpose of camel keeping in this study, The low cost of camel keeping and the fact that camels are drought tolerant animals able to survive in severe conditions compared to other livestock were also offered as reasons for keeping camels. None of the respondents stated the sale of camel milk as an objective of camel keeping, but camel milk was used for home-consumption.

Generally, feed and water supply were considered as constraints in different regions, but were considered to be most serious in Gezira and Gedaref states. This is probably due to the decrease in available range land as a result of the encroachment of mechanizing agriculture on traditional pastures in these two regions. Most of the income of camel owners was spent on the purchase of crop residues in Gezira and Gedaref states. The camel owners in other regions (Sinnar and North Kordofan) solve the shortage of feed and water by adopting a long migration route to the south.

Most respondents in all studied areas reported disease incidence during the past 12 months. The highest percentage incidence was observed in Sinnar state. Trypanosomiasis was found to be the important camel disease in Sinnar, Gedaref and North kordofan; while the mange was observed as an important disease in Gezira state. Trypanosomiasis is an endemic disease in the southern part of the camel belt. The migration pattern of camel owners of Sinnar, Gedaref and North Kordofan state maintain the transmission cycle between the parasite and vector. On the other hand, the study revealed a deficiency

in government veterinary services in comparison with private veterinary services and drug suppliers. This is attributed to the policy of liberalization of the economy and the sudden shift from complete government sponsorship to private veterinary services which provide care at market prices (El-Sammani *et al.*, 1999). As a result, the high cost of veterinary services and drugs put the services beyond the reach of poor herders in rural areas (Musa, 2007).

3:5 Conclusion:

Camels play an important role in the livelihood of people found in dry and semi dry zones, and have potential for greater contribution through better health management, feeding and genetic improvement. Further studies and research to identify the genetic potential of Sudanese camels for milk and meat production and racing ability are needed to use the information in different programs of genetic improvement. A functional recording system is an important component of genetic improvement. Such a system was not observed in the studied areas and it is extremely important to encourage camel owners to keep records. Unfavorable production conditions (lack of feeds, shortage of water, diseases prevalence and lack of security) were defined. The priority of genetic improvement objective among camel owners was for dual purpose animals (meat and dairy production), while racing ability was given little consideration. A genetic improvement programme for camel breeds could be built on indigenous practices and knowledge through additional support by government authorities.

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Chapter four

Phenotypic characterization and description of Sudanese camels *(Camelus dromedarius*)

Abstract

Data on phenotypic measurements and descriptions were obtained on 274 camels (different ecotypes). The purpose of this study was to characterize and re-grade some of Sudanese camel breeds according to their morphological traits. The results of this study showed that average barrel girth, heart girth, height at shoulders and body weight were 2.45 ± 0.02 m; 2.02 ± 0.01 m; 1.90 ± 0.01 m and 463.25 ± 4.90 kg respectively. The results also revealed that phenotypic measurements were significantly influenced by type of camel and age group. The Shanbali camel recorded the highest values of barrel girth, heart girth and body weight, followed by those of the Kenani camel. Rashaidi, Anafi and Bishari camel breeds recorded the lowest values. Regarding to the age groups the camels in the second group 7 to 9 years had significantly the highest values of phenotypic measurements, followed by those of the third group 10 to 12 years, while the animals in the first group 4 to 6 years recorded the lowest values. Moreover, the results showed that the sex of camel significantly affected the heart girth, height at shoulders and body weight; and the males had significantly higher ($P < 0.5$) values than those of females. The study concluded that the Shanbali and Kenani camel breeds are the largest Sudanese camel breed followed by Maalia and Maganeen camels.

Key words: Phenotypic measurements, Characterization, Description, Camel breeds, Sudan

4:1 Introduction:

Sudan ranks second in respect to the size of the camel population in the world. Camels constitute 22% of the animal biomass in Sudan and 26.3% of the number of camels in the Arab world (Sakr and Majid, 1998). The last estimation of camels' population in the Sudan was about 3908 thousands head (Ministry of Animal Resources, 2005). Camels in Sudan are spread in a belt configuration; it extends between latitude 12°N to 16°N (Wardeh, 1989). This belt is characterized by erratic rainfall which is < 350 mm. Agab (1993) mentioned that camels in Sudan are concentrated in two main regions; the Eastern region, where camels are found in the Butana plain and the Red Sea hills, and Western regions (Darfur and Kordofan).

Sudanese camels belong to the species *Camelus dromedarius*. These camels had been owned and raised by nomadic tribes, and they migrate north and south according to the season. Camels in the Sudan and elsewhere are classified as pack (heavy) and riding (light) types according to the function they perform and probably as a result of selection applied for these traits by the various camel-owning tribes. The Sudanese heavy type constitutes the majority of the camels kept by nomads in Sudan. In this group two types can be identified on the basis of conformation and tribal ownership: The Arab and Rashaidi camels. On the other hand, the riding camels are restricted to the north-east of the country between the Nile and Red Sea. Two main types are recognized, namely Anafi and Red Sea Hills (Bishari) camels (El-Fadil, 1986). Wardeh (2004) classified dromedary camels into four major classes: beef, dairy, dual purpose and race camel. This

classification is based on the fact that the camel is a major component of the agro-pastoral systems in Asia and Africa. The purpose of this study was to characterize and re-grade some of Sudanese camel breeds according to their morphological traits.

4:2 Materials and methods:

4:2:1 Phenotypic measurements:

Body measurements data were obtained on 274 camels from different breeds. The homeland of Kenani camel breed is Sinnar state, while Rashaidi, Lahwee, Anafi and Bishari breeds are reared in Gedaref state. Butana camel is bred and raised in the Butana plain (Gezira state). Kabbashi, Maalia, Maganeen and Shanbali camels are reared in North Kordofan state (Fig. 4.1). Mature and unrelated camels were randomly selected for characterization. Sex and age of each animal were recorded. The studied measurements were heart girth taken immediately behind the breast pad; barrel girth taken over the highest part of the hump and height at shoulders. The body weights of animals were estimated according to the Boue (1949) formula.

4:2:2 Phenotypic descriptions:

A detailed structural questionnaire was prepared and used to collect information from camel owners in the various areas. Some the information collected during interviews were supported by observation. The questionnaire was designed to obtain information on general characteristics and descriptions of camel such as body colour, hair length and distribution, hump and udder size.

4:2:3 Data analysis:

The SPSS statistical computer software (SPSS for windows, release 15, 2006) was used to analyze the data. Phenotypic

measurements data were subjected to analysis of variance (ANOVA) using the general linear model (GLM). The statistical model used was:

$$Y_{ijkl} = \mu + B_i + S_j + A_k + e_{ijkl}$$

Where Y_{ijkl} is the observation for each trait of the *ijkl*th animal, μ is the general mean of each trait, B_i is the fixed effect of *i*th breed, S_j is the fixed effect of *j*th sex, A_k is the fixed effect of the *k*th age group and e_{ijkl} is the random error effect associated to the *ijkl*th observation. The separation of the means was made according to Duncan's multiple range test (DMRT).

Table 4.1: Phenotypic measurements of Sudanese camel with respect to breed, sex and age group.

Item	No.	Barrel girth (m)	Heart girth (m)	Height at shoulder (m)	Body weight (kg)
Breed:		***	***	***	***
Kenani	31	2.51±0.04^{abc}	2.08±0.02^{a}	1.96±0.01^{b}	501.75±12.08^{a}
Rashaidi	30	2.54±0.04^{a}	1.95±0.02^{b}	1.78±0.02^{e}	427.59±12.82^{c}
Lahwee	30	2.49±0.04^{ab}	1.99±0.02^{b}	1.87±0.01^{d}	450.00±12.37^{bc}
Anafi	30	2.41±0.04^{bcd}	1.97±0.02^{b}	1.86±0.01^{d}	426.90±12.20^{c}
Bishari	30	2.40±0.04^{cde}	1.97±0.02^{b}	1.86±0.01^{d}	427.37±12.46^{c}
Kabbashi	34	2.26±0.04^{e}	1.98±0.02^{a}	1.92±0.01^{bc}	453.19±11.31^{bc}
Maganeen	16	2.50±0.05^{bc}	2.11±0.03^{a}	1.93±0.02^{bc}	499.07±16.91^{ab}
Shanbali	29	2.64±0.04^{a}	2.08±0.02^{a}	1.91±0.01^{c}	516.69±12.48^{a}
Maalia	12	2.37±0.06^{de}	2.13±0.03^{a}	1.98±0.02^{a}	491.11±19.52^{ab}
Butana	32	2.37±0.04^{bcd}	1.93±0.02^{b}	1.89±0.01^{bc}	438.82±11.69^{bc}
Sex:		NS	***	***	**
Male	97	2.45±0.02^{a}	2.05±0.01^{a}	1.93±0.01^{a}	477.57±5.69^{a}
Female	177	2.45±0.02^{a}	1.99±0.01^{b}	1.86±0.01^{b}	448.92±7.60^{b}
Age group:		***	***	*	***
4-6 years	94	2.31±0.02^{b}	1.96±0.01^{b}	1.87±0.01^{a}	416.37±6.86^{c}
7-9 years	89	2.51±0.02^{a}	2.05±0.01^{a}	1.91±0.01^{a}	489.34±7.23^{a}
10-12 years	62	2.50±0.03^{a}	2.04±0.01^{ab}	1.90±0.01^{a}	477.05±8.97^{ab}
≥13 years	29	2.48±0.04^{a}	2.03±0.02^{b}	1.90±0.02^{a}	470.22±12.82^{bc}
Overall	**274**	**2.45±0.02**	**2.02±0.01**	**1.90±0.01**	**463.25±4.90**

Means with the same letters are significantly not different $P > 0.05$.
NS, *, ** and ***: significant at $P > 0.05$, $P < 0.05$, $P < 0.01$ and $P < 0.001$.

4:3 Results:

4:3:1 Phenotypic measurements:

Table (4.1) shows phenotypic measurement of Sudanese camels in respect to breed, age group and sex, however, phenotypic descriptions of Sudanese camel are shown in Tables (4.2) and (4.3). The results of this study revealed that averages of barrel girth, heart girth, height at shoulders and body weight were 2.45 ± 0.02 m; 2.02 ± 0.01 m; 1.90 ± 0.01 m and 463.25 ± 4.90 kg, respectively (Table 1). The results also showed that the breed of camel had a very highly significant ($P < 0.001$) effect on the studied phenotypic measurements. The Shanbali and Kenani camels had significantly ($P < 0.05$) higher values of barrel girth, heart girth and body weight, followed by those of the Maganeen and Maalia camels. However, the Rashaidi, Anafi and Bishari camel breeds recorded the lowest values of the above traits and were significantly ($P < 0.05$) different from those of other breeds. Maalia camel breed was significantly ($P < 0.05$) taller at shoulders (1.98± 0.02 m) than other breeds. The sex of camel had a very high significant ($P < 0.001$) influence on heart girth, height at shoulders and a highly significant ($P < 0.01$) on body weight; while the barrel girth was insignificantly ($P > 0.05$) affected by sex. The data also showed that the male camels had greater heart girth, height at shoulders; and had heavier body weights than those of the females. The results also showed that the age of camel had a very high significant ($P < 0.001$) effect on each of barrel girth, heart girth and body weight, and had a significant ($P < 0.05$) influence on height at shoulders. The age group 7 to 9 years had a significantly ($P < 0.05$) higher values of the above traits, followed by those of the age group 10 to 12 years, then those of the age group ≥13 years. However, the

age group 4 to 6 years had significantly ($P < 0.05$) low values of all measured traits.

Figure 1: Distribution of camel breeds in Sudan

4:3:2 Phenotypic descriptions:

4:3:2:1 Kenani camel: It is also known as the Rufaa camel, found in Sinnar and Blue Nile states, owned by Rufaa, Agilieen, Dighame and Kenana tribes. The predominant colors of these camels are dark brown, grey and yellowish. They are also characterized by long hair covering the whole body especially on the hump and neck. The results showed that averages of abdominal girth, chest girth, height at shoulders and body weight of Kenani camel are 2.51 ± 0.04 m, 2.08 ± 0.02 m, 1.96 ± 0.01 m and 501.75 ± 12.08 kg respectively (Table 4.1). In these camels the hump is well developed, located in the middle of the back. The udder and teat size are medium to large and with a well developed milk vein (Table 4.2, Fig. 4.2 and 4.3). In dry seasons (winter and summer) the camels are usually found in the south of

Sinnar state and North Blue Nile state. However, in the wet Season the owners move with their camels to the north of Sinnar state and White Nile state near Dueim town.

Fig. 4.2: Kenani camel

Fig. 4.3: Kenani camel

Fig. 4.4: Rashaidi camel

Fig. 4.5: Rashaidi camel

4:3:2:2 Rashaidi camel: This camel is reared in eastern Sudan (Gedaref and Kassala states), bred by Rashaida nomadic tribe which migrated from Suadia Arabia to Sudan relatively recently. The dominant colors of these camels are dark grey and pinkish red. These camels are characterized by being short at shoulders; light in weight and have an outstanding ability to survive under drought conditions (harsh environment). The hair of the camels is short to medium; and they have a small hump, large and well developed udder and teats (Table 4.2, Fig. 4.4 and 4.5). The present study revealed that the

averages of abdominal girth, chest girth, height at shoulders and body weight of this camel are 2.54 ± 0.04 m, 1.95 ± 0.02 m, 1.78± 0.02 m and 427.59 ± 12.82 kg respectively (Table 4.1). In dry seasons these camels are moved to Shuwak and Ghabat Al-feel (Gedaref state) and move to the north of New Halfa town (Kassala state) in the wet season.

Fig. 4.6: Lahwee camel

Fig. 4.7: Lahwee camel

4:3:2:3 Lahwee camel: This breed is reared in Gedaref state and is bred by Lahween tribe. The distinguishing colors are brown, red and yellowish. The hair is of medium length, the hump is centrally placed with an erect or bent to the side orientation and the size of udder and teat are medium (Table 4.2, Fig. 4.5 and 4.6). The averages of abdominal girth, chest girth, height at shoulders and body weight of this camel are 2.49 ± 0.04 m, 1.99 ± 0.02 m, 1.87 ± 0.01 m and 450.00 ± 12.37 kg, respectively (Table 4.1). These camels are usually found in Shuwak and Ghabat Al-feel (Gedaref state) in dry seasons and move to Soubag area in the wet season.

4:3:2:4 Anafi camel: This type of camel is generally found in Gedaref state (eastern Sudan); Gezira and Sinnar states (Central Sudan). This breed is always found in small numbers and raised with

other types of camels. It is owned by Rashaida and Lahween tribes (Gedaref state), Shukria, Bataheen and Ahamda tribes (Gezira State), Rufaa and Kenana tribes (Sinnar state). The white color is predominant in this breed, but animals with yellowish color are also found. The hair is short and soft and the hump is small, erect and located in the middle to the back. The animals have small udders and teats (Table 4.2, Fig. 4.8 and 4.9). The weight of the studied mature animals was 426.90 ± 12.20 kg, and the averages of barrel girth, heart girth and shoulders height were 2.41 ± 0.04 m, 1.97 ± 0.02 m and 1.86 ± 0.01 m respectively (Table 4.1).

Fig. 4.8: Anafi camel

Fig. 4.9: Anafi camel

4:3:2:5 Bishari camel: This camel is mainly reared in eastern Sudan (Kassala and Gedaref states). It is bred by Bishareen, Amar'ar, Beni Amir and Hadendowa tribes; it is also bred with other tribes (Shukria, Lahween) in small numbers with other types. This breed is distinguished by its white or yellowish coat color, short hair and concave face profile. The size of the hump is small to medium, located in the middle of the back, and with erect orientation. The udder and teats of Bishari camel are small sizes (Table 4.2, Fig. 4.10 and 4.11). The averages of barrel girth, heart girth, shoulder height and body

weight of this breed are 2.40 ± 0.04 m, 1.97 ± 0.02 m, 1.86 ± 0.01 and 427.37 ± 12.46 kg respectively (Table 4.1).

Fig. 4.10: Bishari camel

Fig. 4.11: Bishari camel

Fig. 4.12: Kabbashi camel

Fig. 4.13: Kabbashi camel

4:3:2:6 Kabbashi camel: This breed is found in North Kordofan state owned by Kababish tribe. The main colors of this breed are grey, red and yellow. The hair length is medium or long, the hump size is small; with erect orientation and located in the middle of the back and the size of the udder and teats are medium (Table 4.3, Fig. 4.12 and 4.13). The averages of abdominal girth, chest girth, height at shoulders and body weight of Kabbashi camel were 2.26 ± 0.04 m, 1.98 ± 0.02 m, 1.92 ± 0.01 m and 453.19 ± 11.31kg, respectively (Table 4.1). The Kawahla and Hamar camels have similar features to the Kabbashi

camel. These camels' owners reside near Obied town in the dry season and move to the north (Soudari area) in the wet season.

Fig. 4.14: Maganeen camel

Fig. 4.15: Maganeen camel

4:3:2:7 Maganeen camel: This camel is raised in North Kordofan state, bred by the Maganeen tribe. The dominant colors are grey, red and yellowish. The hair length is short to medium. The camels have a large hump with an erect orientation, located in the middle to the back. They have large udders and teats and have straight, short and medium hair length (Table 4.3, Fig. 4.14 and 4.15). The averages of abdominal girth, chest girth, height at shoulder and body weight of Maganeen camel are 2.50 ± 0.05 m, 2.11 ± 0.03 m, 1.93 ± 0.02 m and 499.07 ± 16.91 kg, respectively (Table 4.1). Some of this camel's owners move in the dry seasons to South Kordofan state near Kadugli and return to Mazroob area in the wet season. Other owners stay in Mazroob in the dry season and move north to Gabel Al-ain in the wet season.

4:3:2:8 Shanbali camel: This camel is found in North and South Kordofan states. It is bred by Shanabela and Awamera tribes; who move with their camels between these two states in different seasons. The main colors of the breed are brown, red, grey and yellow; the hair is straight and long, and the hump is well developed, centrally placed

with erect or bent sideways orientation (Table 4.3, Fig. 4.16 and 4.17). This camel breed is characterized by heavy weight 516.69 ± 12.48 kg on average. The means of barrel girth, heart girth and shoulders height are 2.64 ± 0.04 m, 2.08 ± 0.02 m and 1.91 ± 0.01, respectively (Table 4.1).

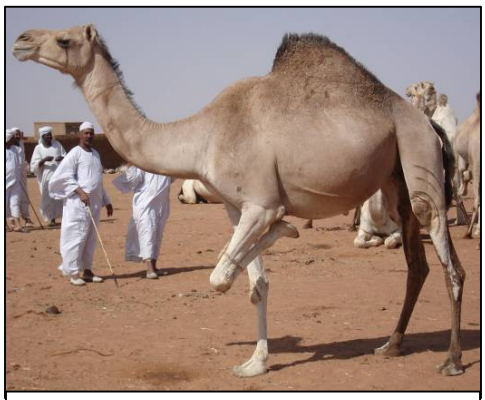

Fig. 4.16: Shanbali camel

Fig. 4.17: Shanbali camel

4:3:2:9 Maalia camel: This breed of camel is found in North and South Kordofan states. It is bred by Maalia and Maagela tribes. These tribes spend the dry season in South Kordofan state (near Kadugli and Dilling towns) and move to North Kordofan state (Mazroob area) in the wet season. The camel color varies between red, grey and yellow; the hair is long and straight; the hump is large and well developed, located in the middle; with erect orientation and the udders and teats are of large sizes (Table 4.3, Fig. 4.18 and 4.19). This camel is quite high at shoulders (1.98 ± 0.02 m), weighed 491.11 ± 19.52 kg and its barrel girth and heart girth averages were 2.37 ± 0.06 m and 2.13 ± 0.03 m, respectively (Table 4.1).

4:3:2:10 Butana camel: This camel breed is found in the Butana plain (east of Gezira state). These camels have different names depending on the tribe of its owners. It is bred by Shukria, Ahamda, Maghareba and Bataheen tribes. The red and grey are the

distinguishing colors of this breed. The hair length is short to medium; the hump size is medium, with erect or sideways orientation and located in the middle to the front of back (Table 4.3, Fig. 4.20 and 4.21). The camel weighed 438.82 ± 11.69 kg; its averages of barrel girth, heart girth and shoulders height are 2.37 ± 0.04 m, 1.93 ± 0.02 m and 1.89 ± 0.01 m, respectively (Table 1). In the dry season (Nov. - June) these camels move near Tambool town, while in the wet season they are found in Soubag area.

Table 4.2: Phenotypic descriptions of the Kenani, Rashaidi, Lahwee, Annafi and Bishari camel breed in the Sudan.

Breed	Kenanni	Rashaidi	Lahawee	Anafi	Bishari
Body color	Dark brown, grey	Reddish, dark grey	Red, brown, yellowish	White, yellowish	White
Color pattern	Uniform	Uniform	Uniform	Uniform	Uniform
Hair length	Medium, long	Short, medium	Medium	Short	Short
Wool distribution	Whole body	Whole body	Whole body	Whole body	Whole body
Face profile	Flat	Flat	Convex	Flat	Concave
Rump profile	Roomy	Flat	Slopping	Flat	Flat
Hump size	Large, medium	Small, medium	Large	Small	Small, medium
Hump orientation	Erect	Erect	Erect, bent sideways	Erect	Erect
Hump location	Middle, to the back	Middle	Middle	Middle, to the back	Middle
Ears size	Large	Large	Large	Large	Medium
Ears orientation	Erect	Backward	Erect	Forward	Backward, erect
Tail base	Thick	Thin	Thick	Thin	Thin
Tail length	Long	Medium	Medium	Long	Long
Udder size	Large, medium	Large	Medium, large	Rudimentary	Rudimentary
Teat size	Large, medium	Large	Medium, large	Rudimentary	Rudimentary

Fig. 4.18: Maalia camel

Fig. 4.19: Maalia camel

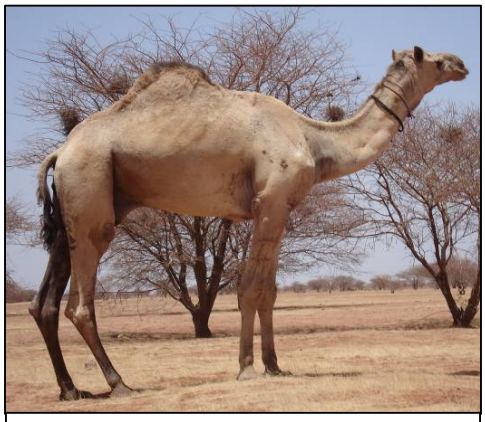

Fig. 4.20: Butana camel

Fig. 4.21: Butana camel

4:4 Discussion:

The results showed significant differences in phenotypic measurements among breeds. Shanbali and Kenani camels recoded the highest values of phenotypic measurements followed by those of the Maganeen and Maalia breeds. These large breeds have long distances to cover during their seasonal north-south movements in search of water and pasture. Shanbali, Maganeen and Maalia camels spend the wet season in North Kordofan state (Um-bader area), and move to South Kordofan state (near Kadugli city) in the dry season. Kenani camels on the other hand are found in the White Nile state (Dueim town) during the wet season and in the dry season they move to southern Sinnar state and Blue Nile state. The long movement route of

these camels tread offers them the best and most diverse types of feeds (trees, shrubs, grasses and crop residues). Other ecotypes such as Butana (Gezira state), Lahawee, Rashaidi (Gedaref state) and Kabbashi (North Kordofan state) camels have short movement routes and usually suffer from shortage of feeds in the dry season. These camels graze mainly shrubs and grasses in the wet season; and crop residues in the dry season. On the other hand, Anafi and Bishari camels recorded the lowest values of phenotypic measurements and are described as riding camels. This is probably as a result of good selection applied to the light weight over a long period of time.

The sex of camel had a significant influence on heart girth, height at shoulders and body weight. Male camels had higher values of heart girth, height at shoulders and body weight compared to those of the she-camels. This finding is in agreement with that of Mehari *et al*. (2007) and Dioli *et al.* (1992) who stated that there is quite distinctive sexual dimorphism in camels, i.e. the male camel is usually taller and of heavier in weight than those of the female. The higher values of the measured traits of male camels may be due to the hormonal secretions and activities in the different sexes. The results of this study showed that the age of camel had a significant effect on the studied phenotypic measurements. The age group 7 to 9 years had significantly higher values of the above traits, followed by those of the age group 10 to 12 years, then those of the age group ≥13 years. However, the age group 4 to 6 years had significantly lower values of tested traits than those of the other age groups. This means that the camels reach maturity (growth peak) within 7 to 9 years; after which the different measurements decline. This trend is reflected in the growth curve of the Sudanese camels.

Table 4.3: Phenotypic descriptions of the Kabbashi, Maganeen, Shanbali, Maalia and Butana camel breed in the Sudan.

Breed	Kabbashi	Maganeen	Shanbali	Maalia	Butana
Body color	Red, grey, yellow	Grey, red, yellowish	Brown, red, grey, yellow	Red, grey, yellow	Red, grey
Color pattern	Uniform	Uniform	Uniform	Uniform	Uniform
Hair length	Medium, long	Short, medium	Long	Long	Short, medium
Hair straightness	Curly	Straight	Straight	Straight	Straight
Wool distribution	Whole body	Whole body	Whole body	Whole body	Whole body
Face profile	Flat	Flat	Flat	Flat	Flat
Rump profile	Flat	Roomy	Roomy	Roomy	Flat
Hump size	Small	Large	Large	Large	Medium
Hump orientation	Erect	Erect	Erect, bent sideways	Erect	Erect, bent sideways
Hump location	Middle	Middle, to the back	Middle	Middle	Middle, to the front
Ears size	Medium	Medium	Medium	Large	Large
Ears orientation	Erect	Erect	Erect	Erect	Erect
Tail base	Thin	Thick	Thick	Thick	Thick
Tail length	Short, medium	Long	Long	Long	Long
Udder size	Medium	Large	Large	Large	Medium
Teat size	Medium	Large	Large	Large	Medium

The results of the phenotypic descriptions revealed that most ecotypes generally have more or less similar morphological features (grey, brown, yellow color, large size, heavily built animals with a developed hump) except for the Rashaidi, Anafi and Bishari breeds. These ecotypes are classified as pack (heavy) camels and called Arabi camel. Gillespie (1962) reported that the pack camel comprises 90% of the total number of camels in Sudan. It is characterized by large, heavily built body, with capacity for developing a relatively large hump and includes the Arabi type and Rashaidi camel. He also added

that the Arabi type is subdivided into three breed types viz: light Pack, big Arabi and heavy Arabi. The Arabi camels in this study can be grouped into the above three types. Shanbali, Kenani, Maalia and Maganeen camels can be classified as heavy Arabi type; while Kabbashi and Lahwee camels may be grouped in the big Arabi type; the Butana can be considered a light pack type. The Rashaidi camel is also classified as a pack camel but it has different phenotypic characteristics (dark grey, pinkish red color, light weight and short at shoulders) compared to other Sudanese pack camels. The Rashaidi camel breed is probably genetically different from the other pack camels of Sudan because of its relatively recent migration from Saudia Arabia and until now it is not cross bred to any large extent with local breeds. Moreover, the Rashaidi breed has large size udders and well developed milk vein which may qualify it to be classified as a dairy camel. These findings are similar to those reported by Wardeh (2004). Regarding the udder and teats feature, Shanbali, Kenani, Maalia, Maganeen and Lahwee camel have well developed udders (medium to large size). This probably explains their capacity in milk production and may be classified as dual purpose camels. The semi intensive farms of camel milk production around cities use the Shanbali camel breed for milk production in flying herds, an indication of the ability of Shanbali camel (Arabi camel) in milk production. Further studies are needed to investigate and evaluate the performance of Shanbali camel and other Arbi breeds for milk production.

The results of these phenotypic descriptions also showed that the Anafi and Bishari breeds have similar features (white, yellowish color and light weight). Different crosses of Anafi camel with pack camels (Lahwee, Kenani, Butana and Rashaidi) were found in

Gedaref, Gezira and Sinnar states. This is probably because Anafi camel is not usually bred in separate herds; but rather always bred with other camel types. The Bishari camel is stronger and slightly heavier than the Anafi camel, and it is bred in pure herds and with other types (Lahwee and Rashaidi camels) in eastern Sudan. Anafi camel is faster than Bishari camel, but reputed to be not suitable for long distance riding. Generally this study reveals that the Shanbali camel is the largest camel breed in North and South Kordofan states (western Sudan) followed by Maalia and Maganeen camels. While Kenani camel is the largest camel breed in central and eastern Sudan.

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Chapter five

Molecular genetic characterization of the *growth hormone* gene in some Sudanese camel breeds

Abstract:

The objectives of this study were the identification of allelic variants of *growth hormone (GH)* gene in six Sudanese camel breeds (Kenani, Lahwee, Rashaidi, Anafi, Bishari and Kabbashi) and estimation of correlations between body measurements and DNA polymorphisms of the *GH* gene. A length of 1732 bp, spanning the region between -44 bp upstream of the first exon and +37 bp downstream of the last exon was sequenced in 2 animals from each breed. The comparison of Sudanese camel *GH* sequences with the GenBank sequence identified one single nucleotide polymorphism (SNP). The SNP was detected in the non coding region (intron 1) in position AJ575419:g.419C>T. A PCR-RFLP method was used to genotype 181 animals representing the six tested Sudanese breeds for detected SNP. Bishari and Anafi breeds that are classified as riding camels had slightly higher T allele frequencies (0.57 and 0.48, respectively) than those of the other four breeds which are classified as pack camels. The effect of breed on all studied traits was highly significant, while the effect of genotype with regard to the SNP g.419C>T on those traits was not significant. The effect of age of animal on abdominal girth, chest girth and body weight was highly significant. Sex had significant effects on chest girth, height at shoulder and body weight.

Key words: Camel breeds, Growth hormone, Single nucleotide polymorphisms, Characterization, Sudan

5:1 Introduction:

Camels provide mankind with a range of products and services, e.g. wool, meat, milk and draught power. They have been domesticated about 3000 years ago and are most numerous in the arid parts of Africa (approximately 11.5 million animals in this region in 1992), particularly in the arid lowlands of Eastern Africa (Somalia, Sudan, Ethiopia, Kenya and Djibouti) (Schwartz and Dioli, 1992). The most recent estimate of camel population in the Sudan was about 3908 thousands heads (Ministry of Animal Resources, 2005). Camels in Sudan are raised in a belt which extends between latitudes 12° N and 16° N (Wardeh, 1989).

Genetic polymorphisms are playing an increasingly important role as genetic markers in many fields of animal breeding and camels are no exception. With the development of molecular genetic techniques, it has become possible to establish a new class of genetic markers based on variability of DNA sequence level (Chung *et. al.* 1998). Besides analysis of microsatellite alleles, polymerase chain reaction and restriction fragment length polymorphism (PCR-RFLP) provide the possibility of the practical application of polymorphic genetic markers to livestock improvement (Soller and Beckmann, 1982). The discovery of RFLP renewed the interest in the use of genetic marker loci as an aid to selection programs. If one (or several) of these RFLP markers are associated with economic trait loci, they can be used as selection criteria. In a breeding scheme, use of phenotypic data coupled with genetic marker data provides more information than phenotype data alone. The use of information on genetic markers is expected to increase genetic progress through increasing accuracy of selection, reduction of generation interval and

increasing selection differentials (Soller and Beckmann, 1983; Kashi *et. al*., 1990; Meuwissen and Van Arendonk, 1992).

The growth hormone, somatotrophin, is a protein hormone of about 190 amino acids that is synthesized and secreted by cells called somatotrophs in the anterior pituitary gland. It is a major participant in the control of several complex physiological processes including growth, metabolism, lactation and mammary gland development in animals. The camel *growth hormone* (*GH*) gene extends over about 1900 bp, and like other mammalian *GH* genes; it splits into 5 exons and 4 introns (Maniou, *et al* 2001). Until now most characterization of candidate genes has been done in cattle (Lucy *et al*., 1991, Schlee *et al*. 1994 and Ge *et al.* 2003), sheep (Wallis *et al.* 1998 and Bastos *et al.* 2001) and goats (Neelam Gupta, *et al.* 2007, Wallis *et al.* 1998), whereas work on camels was meagre. Allele variants differ from breed to breed in their occurrence and frequency.

The aim of this study was to sequence the *growth hormone* (*GH*) gene in Sudanese camel breeds looking for single nucleotide polymorphisms (SNPs) and estimating correlations between body measurements and SNPs of *GH* gene.

5:2 Materials and methods:

5:2:1 DNA extraction:

Hair samples were obtained from 181 unrelated individuals of Sudanese camels. Thirty one hair samples were obtained from Kenani (KEN) and 30 hair samples were obtained from each of the Rashaidi (RAS), Lahwee (LAH), Anafi (ANA), Bishari (BIS) and Kabbashi (KAB) breeds. Genomic DNA was extracted from hair roots by using Nucleospin® tissue kit (Macherey-Nagel). DNA concentration was measured with a spectrophotometer (NanoDrop).

5:2:2 DNA amplification with polymerase chain reaction (PCR):

Based on the published nucleotide sequence information of the camel *GH* gene (GenBank accession no. AJ575419, Maniou *et al.* 2004) primer pairs were designed to amplify four *GH* fragments (Kgh1b, Kgh1, Kgh2 and Kgh3) by using primer3 program (http:// biotools. umassmed. edu/bioapps/primer3_www.cgi). The gene from -44 bp upstream of the first exon to +37 bp downstream of the last exon was analyzed. The primer sequences, location and size of the amplified fragments are shown in Table (1). PCR was performed in a reaction volume of 25 µl using 100 ng of DNA, 0.2 mM of each primer, 1X PCR buffer, 2.5 mM $MgCl_2$, 0.2 mM of each dNTP and 0.5 units of GoTaq flexi-DNA polymerase (Promega).

Table 5.1 The primer sequences, location and size of the amplified fragments

Name	Annealing temperature (°C)	Product size (bp)	Sequence (5'-3')
KGH1B up	56	508	cagggaccaattccaggat
KGH1B low			ccatccctgaggagcttaca
KGH1 up	51	613	gtcctgtggacagctcac
KGH1 low			tgtcctcctcactgcttta
KGH2 up	57	671	tcaggatgggtgctagtg
KGH2 low			tggtgaagaccctgctgag
KGH3 up	57	687	cttctcgctgctgctcatc
KGH3 low			gcactggagtggcactttc

The amplification programs consisted of 37 cycles. The first one was characterised by denaturation at 94 °C for 2 min, annealing with the special primer temperature (Table 5.1) for 30 s and an extension step at 72°C for 40 s. The next 36 cycles involved a denaturation step at 94 °C for 1 min, annealing at 51 to 57 °C for 30 s and extension at 72 °C for 40 s with the exception that in the last cycle

the extension time was 10 min. The PCR products were visualized by ethidium bromide staining following electrophoresis on 2% agarose gel (Biorad) in TAE buffer and photographed under UV light.

5:2:3 Sequence analysis:

Two animals of each breed were sequenced. The PCR products amplified by using the standard methods were cut from agarose gel (2%) and purified using JustSpin Gel Extraction columns (Genaxxon). Nucleotide sequencing was carried out according to the dideoxynucleotide chain-termination technique (Sanger *et al*., 1977) by using a BigDye™ Terminator v1.1 Ready Reaction cycle sequencing kit and an ABI PRISM 310 nucleotide sequencer (Applied Biosystems).

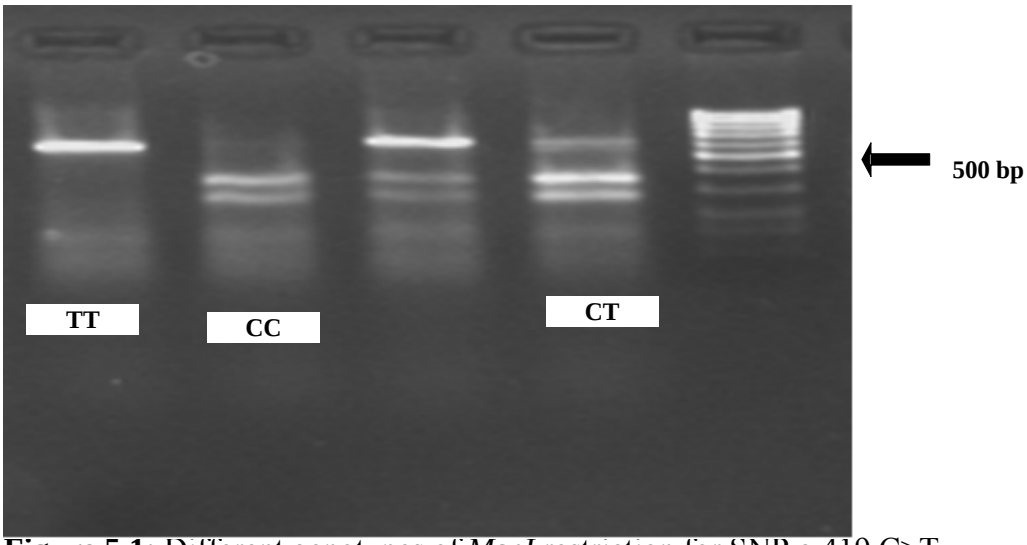

Figure 5.1: Different genotypes of *MspI* restriction for SNP g.419 C>T

5:2:4 Genotyping:

The 181 animals of the six tested Sudanese camel breeds were genotyped for SNP AJ575419:g.419 C>T (intron 1) using the PCR-RFLP method. A 613 bp fragment (primer pair KGH1) covering the sequence containing the mutation site was amplified. The amplicon was digested with *MspI* restriction endonuclease (Promega) at 37° C

for four hours, to distinguish between the two alleles. For each reaction, 15 µl of PCR product, 2 µl buffer, 2.5 µl H_2O and 0.05 µl enzyme containing 5 units of *MspI* were used. The digested fragments (C allele, unrestricted: 613 bp; T allele, restricted: 349 bp and 264 bp) were analyzed by electrophoresis in 2% agarose gels, stained with ethidium bromide and photographed under UV light (Figure 5.1).

5:2:5 Phenotypic measurements:

Chest girth was measured immediately behind the breast pad; abdominal girth was determined over the highest part of the hump and the shoulder height was measured for each animal. Weights of animals were then estimated using the Boue formula (1949). The age and sex of each animal were also recorded.

5:2:6 Statistical analysis:

Genotype and allele frequencies were determined by gene counting. The Chi-square test was employed to evaluate whether the populations were in Hardy-Weinberg equilibrium. However, the t-test was used to determine differences in gene frequencies between populations. The data on the estimation of body weights and phenotypic measurements of the different genotypes were subjected to analysis of variance (ANOVA) using the general linear model (GLM) from the Statistical Analysis Software (SAS Institute Inc., 2000). The statistical model used was:

$$Y_{ijklm} = \mu + A_j + B_i + S_k + G_l + e_{ijklm}$$

Where Y_{ijklm} is the observation on each trait of the *ijklm*th animal, μ is the general mean of each trait, A_j is the covariance of *j*th age, B_i is the fixed effect of *i*th breed, S_k is the fixed effect of *k*th sex, G_l is the fixed effect of the *l*th genotype and *eijklm* is the random error effect associated to the *ijklm*th observation.

5:3 Results:

5:3:1 Sequencing of *GH* gene in Sudanese camel:

The nucleotide sequence of the *GH* gene of Sudanese camel resulted in 1732 bp, spanning the region between -44 bp upstream of the first exon and +37 bp downstream of the last exon. The comparison of the tested six Sudanese camels breeds *GH* sequences with the references of GenBank sequence (AJ575419) descending from dromedary camels identified one single nucleotide polymorphism (SNP). The SNP was detected in a non coding region (intron 1) in position g.419C>T relative to the GenBank sequence.

5:3:2 Genotyping of polymorphisms:

The genotype frequencies of the SNP g.419C>T in intron 1 in Sudanese camel are listed in Table (5.2). All camel breeds were found to be carriers of the T allele with an allelic frequency ranging between 0.30 for LAH breed and 0.57 for BIS. The heterozygous (CT) was most frequent among the RAS breed and least frequent among KEN breed. The homozygous (TT) had the highest genotype frequency in BIS and ANA breeds, while the homozygous genotype (CC) was most frequent among LAH and KEN breeds. The chi-square (χ^2) test showed that each breed was in conformity with the Hardy-Weinberg equilibrium (HWE) ($p < 0.01$). Differences in genotypes and alleles frequencies between breeds were tested for significance using the t-test. The results showed significant differences in allele frequency between the breeds. The frequency of T allele in BIS breed was with 0.57, which was significantly higher than in all those of other breeds except ANA breed.

Table 5.2: Genotype and allele frequencies of SNP g.419 C >T in *GH* gene in Sudanese camel breeds

Breed	Genotypes			Alleles	
	TT	TC	CC	T	C
Kenani	0.19	0.26	0.55	0.32[a]	0.68
Rashaidi	0.10	0.47	0.43	0.33[a]	0.67
Lahwee	0.17	0.27	0.57	0.30[a]	0.70
Anafi	0.30	0.37	0.33	0.48[ab]	0.52
Bishari	0.37	0.40	0.23	0.57[b]	0.43
Kabbashi	0.13	0.40	0.47	0.33[a]	0.67
Overall	0.21	0.36	0.43	0.39	0.61

Allele frequencies having the same superscript are not significantly different (P > 0.05)

5:3:3 Phenotypic measurements:

The data in Table (5.3) presents the least squares means and standard errors of abdominal girth, chest girth, shoulder height and body weight. The estimated least squares means of abdominal girth, chest girth, height at shoulder and body weight were 2.42 ± 0.02 m, 1.97 ± 0.01 m, 1.86 ± 0.01 m and 439.05 ± 4.75 kg respectively. These results (Table 3) indicated that the breed had a significant (P < 0.01) influence on all studied traits, while the SNP g.419C>T genotypes had no significant effects (P > 0.05) on those traits. The results also revealed that age of animal significantly (P < 0.01) influenced abdominal girth, chest girth and body weight. Sex had a significant (P < 0.01) effect on chest girth, height at shoulders and body weight. The results also showed that KEN breed had significantly higher values for chest girth (2.08 ± 0.02 m) and body weight (501.65 ± 11.79 kg) compared to the other breeds. Male camels had a significantly (P < 0.05) greater chest girth, shoulder height and heavier body weight than the corresponding traits of female camels. In addition, the homozygous genotype of the SNP g.419 (TT) had the highest, but not significantly different (P > 0.05) abdominal girth, chest girth, height at

shoulders and body weight; followed by those of the heterozygous (TC), while the homozygous (CC) had lowest values.

Table 5.3 Least square means and standard errors of abdominal girth (AG), chest girth (CG), shoulder height (SH) and body weight (BW)

Parameter	No.	AG (m) Mean ± s.e.	CG (m) Mean ± s.e.	SH (m) Mean ± s.e.	BW (kg) Mean ± s.e.
Age		**	**	NS	**
Breed		**	**	**	**
Kenani	31	2.51 ^{b} ±0.04	2.08 ^{b} ±0.02	1.95 ^{c} ±0.01	501.65 ^{b} ±11.79
Rashaidi	30	2.58 ^{b} ±0.04	1.96 ^{a} ±0.02	1.78 ^{a} ±0.01	439.10 ^{a} ± 12.76
Lahwee	30	2.50 ^{b} ±0.04	1.99 ^{a} ±0.02	1.86 ^{bc} ±0.01	452.48 ^{a} ± 12.62
Anafi	30	2.40 ^{b} ±0.04	1.96 ^{a} ±0.02	1.86 ^{b} ±0.01	424.83 ^{a} ±11.94
Bishari	30	2.38 ^{ab} ±0.04	1.97 ^{a} ±0.02	1.86 ^{b} ±0.01	424.37 ^{a} ±12.34
Kabbashi	30	2.23 ^{a} ±0.04	1.97 ^{a} ±0.02	1.92 ^{c} ±0.01	450.67 ^{a} ±11.95
Sex		NS	**	**	**
Female	131	2.43 ^{a} ±0.02	1.96 ^{a} ±0.01	1.84 ^{a} ±0.01	432.02 ^{a} ±6.00
Male	50	2.44 ^{a} ±0.03	2.02 ^{b} ±0.01	1.91 ^{b} ±0.01	465.68 ^{b} ±9.60
SNPg.419 C>T		NS	NS	NS	NS
TT	38	2.48 ^{a} ±0.03	2.01 ^{a} ±0.02	1.88 ^{a} ±0.01	463.21 ^{a} ±10.78
TC	65	2.43 ^{a} ±0.03	1.97 ^{a} ±0.01	1.87 ^{a} ±0.01	442.87 ^{a} ±8.43
CC	78	2.40 ^{a} ±0.03	1.99 ^{a} ±0.01	1.87 ^{a} ±0.01	440.48 ^{a} ±7.86
Overall mean	181	2.42 ±0.02	1.97 ±0.01	1.86 ±0.01	439.05 ±4.75

** Significant at $p < 0.01$; NS not significant ($p > 0.05$)
Means without a common superscript differ significantly ($p < 0.05$).

5:4 Discussion:

GH sequences of the six tested Sudanese camel breeds were aligned and compared with the GenBank camel *GH* sequence AJ575419. Only one SNP was identified in a non coding region (intron 1) in position AJ575419:g.419C>T. It is noteworthy to state that numerous mutations in this gene were documented in other

species, vis: in cattle, more than ten SNPs were recorded (Musa, 2007; Ge *et al.*, 2003; Chikuni *et al*., 1994). Also, many SNPs were reported in sheep (Marques *et al*., 2006**;** Bastos *et al*., 2001). Neelam Gupta, *et al.* (2007) found several SNPs in *growth hormone* gene of Black Bengal goats. The lack of SNPs in *GH* of Sudanese camels may be due to the probability that all these ecotypes may have originated from the same stock and not enough time has passed for segregation and generation of new mutants. The detected SNP in *GH* gene of Sudanese camel was previously reported in Pakistani dromedary camel (Shah, 2006).

Anafi and Bishari breeds tended to have a higher T allele frequency compared to those of the other four breeds. However, the difference in the T allele frequency was significant only between Bishari and the other four breeds. Anafi and Bishari breeds have the same morphological appearance (white coat and relatively light weight), and both are classified as riding camels. This would suggest a probable ancestral linkage between these two breeds. Other breeds (Kenani, Lahwee, Rashaidi and Kabbashi) have higher body weights and are classified as pack camels (draught animals). Generally they have almost similar T allele frequencies (0.30 to 0.33). This SNP is only one of a large probable number of mutations in the whole genome but it is possible that the higher T allele frequency in Anafi and Bishari is the result of a probable similar ancestral origin. However, these suggestions require extensive studies to verify them. The results also indicated that there was no significant association between the each of genotypes TT and TC of the *GH* and the average of each of abdominal girth, chest girth, shoulder height and body

weight. However; further studies with larger numbers of animals are needed to verify this finding.

The camel breed had a significant influence on the studied body measurements. The results of the present study were in agreement with findings of Wardeh, 1989; Wardeh, 2004 and Khouri, 2000 with respect to body weights of Bishari and Anafi riding camel breeds (424.37 and 424.83 kg respectively). Although the remaining four camel breeds have similar body conformation (Wilson, 1984 and Khouri, 2000), yet the Kenani camel was significantly heavier than the others. Male camels had significantly higher values of body measurements than those of the females. This finding is in agreement with that of Mehari *et al*. 2007 and Dioli *et al.* (1992) who stated that there is quite distinctive sexual dimorphism in camels, i.e. the male camel is usually taller and of heavier weight than those of the female. These differences in tested traits between male and female camel may reflect differences in the hormonal secretions and their activities in the two sexes.

5:5 Conclusion:

Dromedary camel contributes significantly to family food security in semi dry and dry climates, and is a major component of the agro-pastoral systems in vast pastoral areas in Asia and Africa. This study demonstrated that only one single nucleotide polymorphism was detected in the growth *hormone* gene of the studied Sudanese camel breeds after sequencing. Differentiation of allele frequencies among camel breeds is significant. This study showed that there were no associations between growth hormone genotypes and body measurements. Further research and more studies with large numbers

of animals are required to investigate these associations between *growth hormone* genotypes and camel body measurements.

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Chapter Six

General discussion

The increase in human population pressure and the decline of per capita production of food in Africa, have resulted in an urgent need to develop previously marginal resources, such as the semi-arid and arid rangelands, and to optimize their utilization through appropriate livestock production systems of which camel production is certainly the most suitable one (Schwartz, 1992). Investments in marginal lands with fragile ecosystems should be approached in a manner that preserves the environment and creates sustainable development. In the Sudan the camel has always been a component of the production systems in marginal lands and will probably be at the centre of development efforts of such areas in the future,

In spite of the camel's contribution to food security in semi dry and dry zones, and its role as a major component of the agro-pastoral systems in vast pastoral areas in Africa and Asia, little is known about its production potential and production systems compared to that of other domestic animals. However, previous works conducted on camels were often concerned with diseases, reproductive physiology and characterization (Mehari *et al.*, 2007). In recent years there has been increasing interest in the camel as an important source of milk, meat, hides and wool in African and Asian countries. Moreover, its cultural importance has been maintained by the introduction of camel racing (Gihad, 1995). On other hand there has been increasing public interest in camel production for milk and meat, which might be due to their nutritive and medical properties.

6:1 Phenotypic characterization:

Characterization of camel breeds and their production systems is considered to be an important first step for any breeding plans of production improvement and utilization of these resources. This work focused on the phenotypic and molecular characterization of Sudanese camel breeds in four representative regions and their production systems. The camels are a major component of the agro-pastoral systems and are kept in a mixed-livestock production system. Livestock were considered the main activity in Sinnar, Gedaref and North Kordofan states, while both livestock and crop farming were the main activity in Gezira state; since both part contributed to camel owners' income. The sedentary management system was adopted in different states, but the transhumant system was found only in Gedaref state (eastern Sudan). The traditional nomadic system was adopted mainly in North kordofan state (Western Sudan) and Sinnar state (central Sudan). The camels in the four states were found to have seasonal north-south movements in search of water and pasture. However, these seasonal movements varied with regard to distances, frequency and duration from one region to the other and also varied within the same region. Camels were raised with other species (cattle, sheep and goats); while keeping camels with sheep and goat were more frequent; because the environments where camels thrive is often more suitable for sheep and goats than for cattle.

In general, the goal of governments is to increase production output and efficiency to ensure an adequate food supply at favourable prices for the human population, while, the smallholder production systems in the tropics are livelihood-oriented and risk-averse, with farmers planning for themselves rather than for the national market

(Wollny, 2003). This may often result in a conflict of interests between the goals of national development and the needs and aspirations of small holders. Camel breeds are kept in all regions in their respective production systems due to their appreciated multi-productive adaptability. Productive traits (milk yield and reproductive rate) have a high priority to generate cash from sale of animals and satisfy the family need for milk. In addition, the low cost of breeding camels, drought tolerance of camels which allows them to survive in severe conditions, serving as a repository of wealth and the high social value placed on camels are very important objectives for keeping camels. Adaptive traits such as disease resistance, ability to utilize poor quality pastures and feeds are also important. The low importance of functions like sale of milk, traction and manure in all regions is probably due to lack of sufficient market interest in camel milk and adoption of new technologies for traction and fertilization. Generally production objectives in all areas are directed to milk production for home consumption and sale of animals for regular cash income.

The results showed that the average milk yield was 1557 ± 672 liter per lactation. Differences between regions were not significant ($P > 0.01$) but camels of Gedaref state had the highest milk yield (1656 liters), followed by camels of Gezira (1515 liters), Sinnar (1508 liters); while camels of North Kordofan produced the least (1489 liters). The high milk production of camels in Gadaref state may be due to the fact that the majority of camels bred in this state are Rashaida camels which are classified as dairy camels. Also the results showed that the average lactation length was 11.48 months with differences between regions being again insignificant ($P > 0.05$).

However; the camels in Sinnar state lactated for a shorter period in comparison with camels in other states. On other hand, the results revealed that the age at first calving and calving interval were significantly ($P < 0.01$) influenced by regions, while the number of services per conception and age of keeping female camels were not affected. The averages of age at first calving, calving interval, number of services per conception and age of keeping female camels were 4.87 ± 0.79 years, 23.09 ± 2.20 month, 1.63±0.55 times and 17.20 ± 4.24 years, respectively.

Most camel owners in all areas had plans or had attempted genetic improvement of their camels but these attempts were not based on sound scientific knowledge and practices. Regarding genetic improvement goals, the priority of genetic improvement is for dual purpose animals (meat and dairy production) while the racing ability was given little consideration.

The camel owners stressed the lack of feeds to be the most important constraint limiting the productivity of their camels. The lack of feed in North Kordofan state is result of the long distance to pasture and grazing areas from watering points, while in Gadaref and Gezira state it is probably a result of the continuous encroachment of mechanized farming on pastureland. The water supply was also considered as a serious constraint jeopardizing the productivity of camels. The shortage of water was very severe in the summer season in Gezira and North Kordofan states because of the shorter interval between every two consecutive drinking times and wells are the only source of water supply. Increasing the number and size of *hafirs* and wells in camel breeding habitats and laws to protect pasturelands from

the extension of mechanized farming may contribute to the improvement of camel production.

Disease prevalence is another important constraint to production and almost all respondents in all areas reported incidences of diseases. Also disease was the main reason for camel losses. Generally the camel owners reported that they obtain veterinary services from private units and drugs suppliers rather than government veterinary services. The liberalization of the economy and the sudden shift from complete government sponsorship to private veterinary services which provide care at market prices put the service beyond the reach of poor herders and rural areas (El-Sammani *et al.*, 1999).

Recording systems were absent in all studied areas. This is probably a result of a lack of understanding of the importance of recording information together with a high percentage of illiteracy among camel owners.

Camels in Sudan are not well classified or defined, with very limited information available on the different ecotypes. An important strategy in the conservation and utilization of animal genetic resources is the dissemination of information on these resources (Musa, 2007). Camels in Sudan and elsewhere were classified into two major classes: riding and pack camels. This classification was suitable to satisfy the needs of caravans, transport and army purposes during the first half of the 20th century (Wardeh, 2004). The raising of camels for packing purposes was not defined as an objective by camel keepers. In Arab counties (Suadia Arabia, Iraq, Syria, Kuwait etc.) camels are classified into two classes: Khawar (for meat and milk production) and Zalol (for racing and riding) (Al-Khouri and Majid 2000). The same classification is adopted by camel herders in Sudan using

different nomenclature. The first class is called *Adbas*s (Sinnar) and the other class is called *Pashendi* (Sinnar) or *Ashab* (Gezira and Gedaref states). Wardeh, (2004) suggested that camels may be classified into four major classes: meat, dairy, dual purpose and race camels. In order that the classification may reflect the production objectives of camel owners in Sudan the classification outlined in figure (6.1) is suggested. It combines Wardeh's suggestion and the traditional classification commonly used by camel herders in Sudan.

This classification of camels in Sudan aims at establishing the foundation for selection of camels on the basis of their performance as meat, dairy, dual purpose and race animals. Moreover, this classification will fit the requirements for the development of camel production and the improvement of the selection standards of their herders.

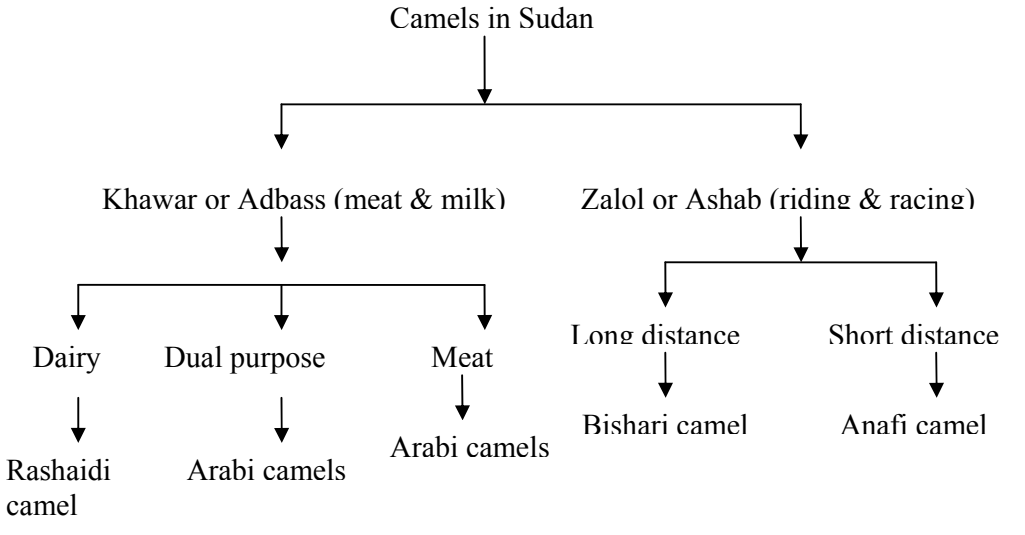

Fig 6.1: Classification of dromedary camels in Sudan

In the literature camels of Kordofan are always classified as pack camels and called Kabbashi camels. In this study the camels of Kordofan were placed in different tribal types according to the tribe that owns the most numbers (Maganeen, Maalia, Shanabela and Kababish). Also, this study includes Kenani camels, which are bred in Sinnar and Blue Nile states, Lahwee camels which are bred in Gadaref state and Butana camels which are bred in the Butana plain (Gezira state). This study showed that the camel ecotype had a significant influence on the studied body measurements (barrel girth, heart girth, height at shoulder and body weight). The results of the present study were in agreement with the findings of Wardeh, (1989); Wardeh, (2004) and Al-Khouri, (2000) with respect to body weights of Bishari and Anafi riding camel breeds (424.37 and 424.83 kg, respectively). Although all the remaining camel breeds have similar body conformation (Wilson, 1984 and Al-Khouri, 2000), and are classified as pack camels, yet the Shanbali and Kenani camels had significantly heavier body weights, followed by those of the Maganeen and Maalia camels. Moreover, the phenotypic characterization data of Shanbali and Kenani camels revealed their good potential for milk production. These camels (Shanbali and Kenani) might be used in any program of selection for meat and milk production (dual purpose). However, further studies are needed to investigate and evaluate the performance of Shanbali and Kenani camels and other Arabi breeds for milk production.

The results of this study showed that the sex of camel had a significant influence on heart girth, height at shoulders and body weight. Male camels had higher values of heart girth, height at shoulders and body weight compared to those of females. This finding

is in agreement with that of Mehari *et al*. (2007) and Dioli *et al.* (1992) who stated that there is quite distinctive sexual dimorphism in camels, i.e. the male camel is usually taller and of heavier weight than those of the female. Also the results of this study showed that the age of camel had a significant effect on the studied phenotypic measurements. The age group 7 to 9 years had significantly higher values of the above traits, followed by those of the age group 10 to 12 years, then those of the age group ≥13 years. However, the age group 4 to 6 years had significantly lower values of tested traits compared to those of the other age groups. This means that the camels reach maturity (growth peak) within 7 to 9 years; after which the different measurements decline. This trend is reflected in the growth curve of the Sudanese camels.

6:2 The Growth Hormone Gene:

This work represents the first attempt to sequence the complete *growth hormone* (*GH*) gene in six Sudanese camel ecotypes (Kenani, Lahwee, Rashaidi, Anafi, Bishari and Kabbashi). The nucleotide sequence of the *GH* gene of Sudanese camel resulted in 1732 bp. The sequence comparison of the tested six Sudanese camel ecotypes *GH* sequences with the reference GenBank sequence (AJ575419) descending from dromedary camels identified one single nucleotide polymorphism (SNP). The SNP was detected in a non coding region (intron 1) in position g.419C>T relative to the GenBank sequence. The lack of SNPs in *GH* of Sudanese camels may be due to the probability that all these ecotypes may have originated from the same stock and not enough time has passed for segregation and generation of new mutants. The SNP g.419 C>T (intron 1) was genotyped by using the PCR-RFLP method and digested with *MspI* restriction

endonuclease. Anafi and Bishari breeds tended to have a higher T allele frequency compared to those of the other four breeds. These two camel types (Anafi and Bishari) have the same morphological appearance (white coat and relatively light weight), and both are classified as riding camels. This would suggest a probable ancestral linkage between these two breeds. Other breeds (Kenani, Lahwee, Rashaidi and Kabbashi) have higher body weights and are classified as pack camels (draught animals); and they have almost similar T allele frequencies. Also, this work showed that there were no associations between *growth hormone* genotypes and body measurements. Further research and more studies with large numbers of animals are required to investigate these associations between *growth hormone* genotypes and camel body measurements.

6:3 Suggestions for genetic improvement:

In what follows we will attempt to offer some suggestions for genetic improvement of Sudanese camels. Improvement goals of camels must be matched with production objectives of the owners, the management potentials and with the prevailing environment. Therefore, production systems, production constraints and available infrastructure must be considered seriously in planning and implementation of a sustainable improvement program.

The interviews with owners have shown that camels are kept due to their appreciated productive potential and adaptability. Productive traits such as growth rate, milk yield and fertility have a high priority as a source of cash income from sale of animals and for the use of milk to satisfy family needs. In addition, adaptive traits such as disease resistance, drought tolerance in addition to the low cost of breeding are extremely important considering the highly unfavorable

production conditions in arid and semi-arid areas. Consequently, it is important to keep the adaptive characteristics at their present level. Generally, genetic improvement goals include the improvement of meat and milk production (dual purpose animals with high growth rate and sustainable lactation milk yield), productive herd-life, tolerance to prevailing disease and fertility traits (age at first calving and calving interval).

The traits related to growth are relatively easy to improve through a breeding program (mass selection) and usually have moderate to high heritability estimates (Hermas, 2009 and Alnajjar *et al.*, 2009). On the other hand, traits related to adaptation are difficult to measure and to select for. In any case, it is difficult to improve upon the present adaptability of most Sudanese camel breeds and hence the main aim will be to prevent any deterioration of adaptability traits. Production traits should be selected in the given production environment (Franklin, 1986), thus allowing adaptation to respond as a correlated set of traits as an option for improving both the production and the adaptation of animals (Horst, 1983).

A young sire breeding system could be adopted in camel production systems and is already practiced. Breeding camels are selected among young males based on information about performance of dam, sire and about their own production performance and evaluation. Enhancing these endogenous practices by introducing performance and pedigree recording and using all available information about relatives, a young breeding camel program seems to be most appropriate. The tribal set up may be used to advantage in organizing such a system. Since each ecotype is mainly raised by a specific tribe the tribal authority can help in the selection and rotation

of sires. A progeny testing scheme is organizationally not applicable, as it too costly and time consuming.

Breeding programs will only be implemented successfully where accurate recording is possible. Accurate record keeping in field populations requires financial means, expertise and well-developed infrastructures such as transport and communication structures. Due to lack of a recording system and a relatively small herd size, breeding programs must be built on alternative means of recording and on different selection methods. Open nucleus breeding schemes with controlled mating and the formation of pedigrees are widely suggested to circumvent the high costs arising from field performance recording and selection. The genetic progress in the nucleus as a result of recording, selection and planned mating, can be disseminated to the participating herds through use of males originating from the nucleus. In such schemes, the best males are kept for breeding in the nucleus, while the remaining selected males are used for breeding in the commercial herds.

It will be necessary to establish four nucleus herds distributed in camels breeding regions: two in Kordofan, Darfour (western Sudan), one in Butana plain (Eastern Sudan) and one in Sinnar state (central Sudan). These nucleus herds will contain mainly Arabi camels which are dual purpose animals (meat and milk). The numbers of females in each herd should be about 400 and 10 males with 1:40 (male: female) ratio. The nucleus herd should be formed by selection of superior females and males from camel populations in the region on the basis of their own performance and performance of dam and sire. The nucleus herd could be kept permanently in station or it may be allowed seasonal movement according to the station circumstances

(availability of feeds and disease prevalence). Traditional natural mating would be practiced in nucleus herds and participants' herds. Breeding camel could be kept 4 to 5 years in herd to prevent inbreeding.

The suggested open nucleus scheme may consist of three levels (Fig. 6.2), the first level is the nucleus herd, and the second level is the propagation herds, while the third level is the herds of camels' owners that were not included in the propagation herds. The camel owners in the second level (propagation herds) are to be selected according to their herd size, willingness to participate and level of education. Also as far as possible they should be able to make and keep records.

Breeding camels and young females not needed in the nucleus herds should be moved to propagation herds, while only superior females are to be moved from propagation herds to nucleus herds. Breeding camels and young females not needed in propagation herds should be transferred to herds in third tier.

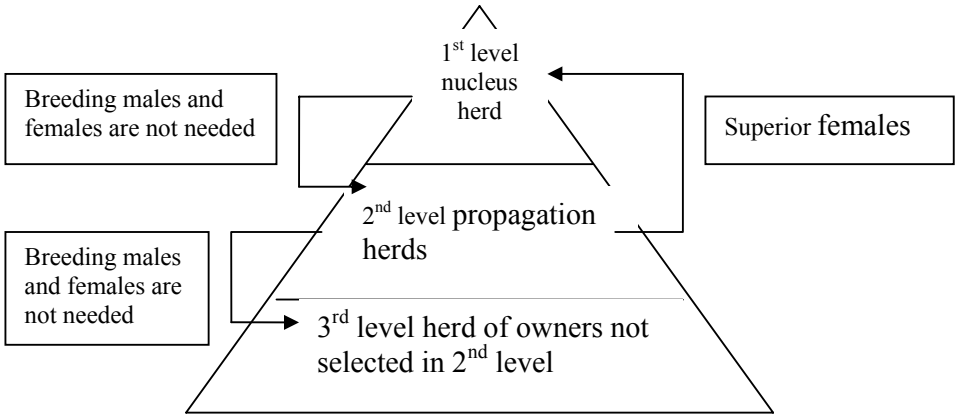

Fig 6.2: Structure of open nucleus breeding scheme for camels

6:4 General conclusions:

The camels are a major component of the agro-pastoral systems and are kept in a mixed livestock-crop production system. Livestock production was considered the main activity in Sinnar, Gedaref and North Kordofan states, while both livestock and crop farming were the main activity in Gezira state; since both activities contribute to camel owners' income. Camels bred were with other species (cattle, sheep and goats); while keeping camels with sheep and goats was more frequent.

The sedentary management system was adopted in a number of different states; while the transhumant system was adopted only by Rashaida tribes in Gedaref state (eastern Sudan). The traditional nomadic system was adopted mainly in North Kordofan state (western Sudan) and Sinnar state (central Sudan). The camels in the four states were found to have seasonal north-south migration patterns in search of water and pasture. However, these seasonal movements varied with regard to distance, frequency and duration among and within regions.

Camels are kept in the dry lands of Sudan in their respective production systems due to their appreciated multi-productive adaptability. However, reproductive rate and milk yield have a high priority to generate cash from sale of animals and satisfy family needs for milk. Regarding genetic improvement goals, the priority of most herders is for dual purpose animals (meat and dairy production), while racing ability has been given a low priority. The genetic improvement of camels must be based on sound scientific knowledge and practices taking into account indigenous knowledge and breeding goals.

Shortage of feed was found to be the most important constraint limiting productivity of camels. Disease prevalence is another

important constraint to production systems and almost all respondents in all states reported incidences of disease. Water supply was also considered a serious constraint jeopardizing the productivity of camels. The shortage of water is very severe in the summer season in Gezira and North Kordofan states.

In this study the camels of Kordofan state were placed in groups based on tribal ownership (Maganeen, Maalia, Shanabela and Kababish). Also, this study includes Kenani camels, which are bred in Sinnar and Blue Nile states; Lahwee, Rashaidi, Anafi and Bishari camels which are bred in Gadaref states and Butana camels bred in the Butana plain (Gezira state). The Shanbali and Kenani camels had significantly heavier body weights, followed by Maganeen and Maalia camels. The phenotypic characterization data of Shanbali and Kenani camels revealed that these ecotypes have good potential for milk production. These camels (Shanbali and Kenani) might be used in any program of selection for meat and milk production (dual purpose). Further studies are needed to investigate and evaluate the performance of Shanbali and Kenani camels and other Arabi breeds for milk production.

At the molecular level the characterization of the *growth hormone* (*GH*) gene involved the genotyping of animals from six Sudanese camel ecotypes (Kenani, Lahwee, Rashaidi, Anafi, Bishari and Kabbashi). After sequencing one single nucleotide polymorphism (SNP) was identified. This SNP was detected in a non coding region (intron 1) in position g.419C>T relative to the GenBank sequence. The SNP was genotyped by using the PCR-RFLP method and digested with *MspI* restriction endonuclease. Anafi and Bishari types (classified as riding camels) tended to have a higher T allele frequency

compared to those of the other four types (classified as pack camels). The results indicated that there was no significant association between genotypes of the *GH* gene and the average of each of abdominal girth, chest girth, height at shoulder and body weight. However; further studies with larger numbers of animals are needed to verify this finding.

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Appendices

Appendix 1: Questionnaires to camel breeders in Sudan

1- General household information

Farmer's name: .....
Village: .....
Farmer Number: .....
Level of education: .....
Age: .....

1.1- Labor distribution in camel production

	Dairy production					
	Feeding	Milking	Breeding	Herding	Health care	Housing
Husband						
Wife						
Sons						
Daughters						
Laborer						

1.2- What types and number of livestock do you keep

a) Camel _____b) Cattle _____ c) Sheep:_____ d) Goats _____.e) other _____

1.3- If you have camels, cattle, sheep and goats, could you rank them according to the relative importance to you?

a) Camel _____ b) cattle _____ c) sheep _____ d) goats _____

1.4- How is composition of your herd?

a) Number of she camel _____ b) Number of she camel U. In. _____ c) Number of camel _____ d) Number of female calves _____ e) Number of castrated camel ____ f) Number of male calves __

2- Herd management

2.1- What is type of your management system?

a) traditional nomadic _____ b) transhumant _____ c) sedentary ___

2.2- Did you migrate or move with animal during year? a) Yes b) No

2.3- If yes: where did you move during a) wet season _____ b) Dry season ____

2.4- Did you sell any camel during the past 12 months? Yes No

2.4.1-If yes: How many? *and fill the table for each animal sold*:

No	Sex	Age	Reason why sold	Condition score
(1)				A ( ) B ( ) C ( )
(2)				A ( ) B ( ) C ( )
(3)				A ( ) B ( ) C ( )

Sex: (m/f); Condition score: A+ healthy, B+ strong, C+ good for breeding
A- sick, B- weak, C- infertile

2.5- Did you buy any camel into the herd during the past 12 months? Yes No

2.5.1- If yes: How many? *and fill the table for each animal bought*

	1	2	3	4	5	6	7	8	9
Sex (m/f)									
Age (years)									

2.6- Did any animals die during the past 12 months? Yes No

2.6.1- If yes: How many? *and fill the table for each animal died:*

No	Sex	Age	Reason of dead
(1)			
(2)			
(3)			
(4)			

3- Farming system:

3.1- Did you grow crops? Yes No

3.1.1- If yes: Did you sell any crops during the past 12 months? Yes No

3.1.2- If yes which crop did you sell?

3.2- What do you consider your main production activity?

a- livestock _____ b- farming _____ c- livestock and farming _____

4- Breeding practices

4.1- Do you keep a breeding camel? YES ____ NO ____

4.1.1- If YES: Why do you keep a camel (s)?

_____

4.1.2- How many breeding camels do you have? _____ What is the breed and age of camel (s) you are owning?

No.	Breed	Age
1		
2		
3		
4		

4.1.3If NO: Why do you not have a breeding camel? _____ _____. (*and go on to question no. 5.6)*

4.2- Where is your breeding camel from?

a) own herd ___ b) other herd ___ c) purchased ___ d) other ___

4.2.1- If (a) own herd: At what age do you select your breeding camel? ____years ____months

4.3- What do you do with camels that are not selected for breeding purposes?

a) castrate ___ b) just leave them in the herd ___ c) sell (before mature) ____ d) other ____

4.4- Do you select your own camel? YES ___ NO ____

4.4.1- If YES: How do you choose a breeding camel, what are the characteristics you use to select your breeding camel?

a) _____ b) _____
c)_____ d) _____
e) _____
4.5- How long do you keep a breeding camel for service? ____years
4.6- Where do you take the replacement breeding camel from?
a) own herd ___ b) other herd ___ c) purchased ___ d) other ___
4.7- Can the replacement camel be the son of the former breeding camel? YES ___ NO ___
4.7.1- If NO: Why not?
_____
4.8- How do you make sure that your breeding camel is fathering the herd? ___
_____

5- Mating organization:
5.1- Do you keep mating records of your camel (s)? If yes how? _____
_____

5.2- What are the mating records you keep (observation of the records)? _____
_____

5.3- In addition to your farm,
5.3.1- For how many farmers do you give service at the moment? _____ farmers
5.3.2- For how many she camels do you give service at the moment? _____ she camels
5.3.3- How many farmers used your camel service last year? _____farmers
5.3.4- What was the total number of she camels served per year per camel last year? _____ she camels
5.4- Do you get a feed back information from the she camels owners about the condition of she camels after service?
a) YES ____ b) NO ____
5.4.1- If your answer yes, what was the number of she camels that got pregnant after serve by your camel last year? _____ she camels
5.5- How much do you charge for one camel service? _____Dinars
(and go to question 5.8)
5.6- If you not using your own camel, do you know the camel serving your she-camel?
a) Yes b) No
5.6.1- If YES: what is the source and breed of the camel you are using for mating
_____

5.7- How much do you pay for one camel service? _____ Dinars
5.8- How long do you keep a she camel for production? ____years
5.9- Do you have a goal to improve your herd? a) milk ____ b) meat _____ c) racing & riding _____
5.10- Do you have plans to improve your herd? a) YES ____ b) NO ____
5.10.1- If YES: how do you want to improve the productivity of your herd?

_____

5.11- What improvement in your herd do you expect from the selection of breeding camel, in may be 20 to 30 years?

_____

5.12- Do you record or keep the performances of your breeding camels (males & females)?

a) Yes _____ b) No _____

5.11.1- If yes, how do you record the performance of your herd? _____

_____

6- Production and reproduction performance:

6.1- What was the average quantity of milk you got from yours she-camel last time and how long did you milk your she camel?

She camel No.	Daily milk yield (l)			Lactation length (months)
	Beginning of lactation	Middle of lactation	End of lactation	
1				
2				
3				
4				

6.2- What was the age of your she-camel when they gave birth to their first calf?

She camel No.	Birth date	First calving date
1		
2		
3		
4		

6.3- When did your She camel give their last calving and previous calving?

She camel No.	Last calving date	Previous calving date
1		
2		
3		
4		

6.4- How many times have you taken yours she-camels for camel before they get pregnant last time?

She camel No.	Number of services
1	
2	
3	
4	

7- Production objectives:

7.1Why do you keep camel?_____(first reply given)

7.2- From the following list, could you rank the reasons according to the degree of importance**?**

Reasons	Rank
Income from sale of milk	
Milk for home-consumption	
Income from sale of animal	
Traction (animal for work)	
Manure	
Insurance against financial problems	
Investment (Like a bank)	

8- Feeding Management, Animal health and Production Constrains:

8.1.1- What do you feed your animals?

a) grazing _____ b) hay _____ c) crop residues _____

d) concentrates _____ e) minerals _____

8.1.1.1- If you use hay, which animals do you supplement with it?

_____

8.1.1.2- If you use concentrates, which animals do you supplement with it?

_____

8.1.2- Do you consider that the feeding is a constraint to your herd production?

8.1.3- Do you consider that the water supply is a constraint to your herd production?

8.1.4- How did you secure water supply to your camels? In wet season

Free_____ Paid _____

8.1.5- How did you secure water supply to your camels? In dry season

Free_____ Paid ____

8.2.1- What are the prevalent diseases in your area?

a) _____ b) _____ c) _____

d) _____ e) _____ f) _____

8.2.2- What is the most important one?

_____

8.2.3- Did you report any diseases among your herd during past 12 months? YES ____NO ____

8.2.3.1- If YES: could you mention them?

a) _____ b) _____ c) _____

d) _____ e) _____ f) _____

8.2.4- If you report any case of disease, where you look for veterinary help from?

a) government veterinary service _____ b) private veterinarians _____

c) drugs suppliers _____ d) others _____

8.3- Could you rank these below constrains according to relative importance?

a) lack of pasture _____ b) security ___ c) lack of water ___ d) diseases _____

e) capital _____ f) labor _____

8.4- What do you consider a more serious constraint to your camel production?

Appendix 2: Trees, shrubs, grasses and herbs browsed or grazed by camels in Gezira and North Kordofan areas

Regions	**Trees and shrubs**	**Grasses and herbs**
Gezira	*Blanites aegyptiaca*	*Digera alternifolia*
	Acacia mellifera	*Ocimum basilicum*
	Acacia seyal	*Polygola erioptera*
	Acacia nubica	*Phyllanthus madraspatensis*
	Acacia senegal	*Achinochloa colonum*
	Acacia nilotica	*Solanum dobium*
		Ipomoea cordofana
		Indegofera errecta
		Plyllanthus nirari (saha)
Kordofan	*Leptradenia pyrotechica*	*Cenchrus biflorus*
	Acacia senegal	*Datyloctenium aegyptiacum*
	Acacia albida	*Echinocloa colonum*
	Acacia nubica	*Tribulus terresteris*
	Blanites aegyptiaca	*Trainthema crystalina*
	Cissus ibuensis	*Ipomoea belopharocepala*
	Calotropis procera	*Eragrostis aspera*
	Acacia etabica	*Citrullus spp*
	Lannea humilis	*Waltheria indica*
	Mangifera indica	
	Acacia tortilis	

Appendix 3: Trees, shrubs, grasses and herbs, browsed or grazed by camels in Sinnar and Gedaref areas

Regions	**Trees and shrubs**	**Grasses and herbs**
Sinnar	*Blanites aegyptiaca*	*Ipomoea cordofana*
	Acacia mellifera	*Indegofera errecta*
	Acacia seyal	*Sorghum aethiopicum*
	Acacia nubica	*Sorghum bicolor (straw)*
	Acacia Senegal	*Dactyloctenium aegyptiacum*
	Acacia nilotica	*Denebra retroflexa*
	Ziziphus spina-christi	*Sesamum indicum (straw)*
	Cadaba farinose	*Ipomoea belpharosepala*
	Dichrostadhys glumerata	*Justicia palustris*
	Capparis deciduas	*Desmodium dicotymum*
		Plyllanthus nirari
		Setaria pallide-fusca
		Ischaemum afarum
		Cymbopogon nervatus
		Trianthema crystalina
Gedaref	*Blanites aegyptiaca*	*Crotataria senegalensis*
	Acacia mellifera	*Ablmoscus spp.*
	Acacia seyal	*Sonchus cornutus*
	Acacia nubica	*Sesbanis sesban*
	Acacia Senegal	*Ipomoea cordofana*
	Acacia nilotica	*Indegofera errecta*
	Ziziphus spina-christi	*Sorghum bicolor (straw)*
	Capparis deciduas	*Sesamum indicum (straw)*
		Ipomoea belpharosepala
		Ischaemum afarum
		Plyllanthus nirari