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Analysis of an emerging peri-urban camel production in Isiolo County, Northern Kenya

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Abstract

A study was conducted to analyse an emerging peri-urban camel production system in Isiolo County (northern Kenya), using the traditional pastoral camel production system as reference. Data was obtained from camel keepers through cross-sectional surveys in both systems, complimented by a focus group discussion with camel producers and camel milk. The results indicate that peri-urban camel production in Isiolo begun early 1990s and evolved to the present market-oriented production system. The gender of the majority of camel keepers in systems were males, however, there were more male camel owners in the pastoral system. Most camel owners in both systems had no formal/secular education (63.3 and 85.7 % for peri-urban and pastoral, respectively). Camels ranked as the most important livelihood source in both systems followed by sheep and goats. Milk for sale was more (P<0.01) important amongst camel keepers in peri-urban than in the pastoral system, whereas sale of progeny, transportation and socio-cultural roles were ranked important (P<0.01, P<0.001 and P<0.01, respectively) in the pastoral system. The majority (60%) of camel keepers within the peri-urban production system built their herds through purchase of foundation stock, whereas those (81.4%) in the pastoral system built theirs mainly through inheritance. The camel herd structures in the two systems were similar, except breeding males were higher (P<0.05) in the pastoral systems. The major constraints facing camel producers in both systems were camel diseases, inadequate feed resources and milk spoilage. The significance of these findings in the two systems is discussed. It is concluded that camel production in peri-urban areas near towns like Isiolo is gaining significance as an economic activity due to commercialization of camel milk.

Keywords: arid and semi-arid lands, camel, Kenya, peri-urban

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Introduction

Kenya consists of about 80% arid and semi-arid lands (ASALs) (Okoti et al., 2004), inhabited by about 30% (approx. 12 million) of the country's population. Northern Kenya mainly comprises of ASALs, exemplified by the County of Isiolo. There are 22 other ASAL Counties in Kenya with different human and camel populations. These ASALs are characterized by high ambient temperatures and low rainfall (usually less than 400 mm annually) (Sombroek et al., 1982) that is highly variable in space and

time. Frequent droughts, the latest one in 2010/2011, are quite common and often cause loss of livestock and sometimes human lives. Extensive livestock production, through nomadic pastoralism, is therefore the most suitable form of utilising these ASALs (Sombroek et al., 1982; Behnke and Scoones, 1993). It is estimated that over 60% of all livestock in Kenya is found in the ASALs, where it employs about 90% of the local population (MoLD, 2010). Kenya's ASALs, however, have the highest incidence of poverty and very low access to basic social services such as infrastructure, education and health facilities.

Of all the animals kept in Northern Kenya, camels are most adapted to the prevailing harsh environmental conditions in ASALs (Rutagwenda et al., 1989; Schwartz, 1992; Guliye et al., 2007). Camels play multiple roles central to the livelihoods and culture of nomadic pastoralists in northern Kenya (Guliye et al., 2007), notably provision of milk and meat, a means of transport, and sources of income from sale of live camels and camel products. Thus, camels play an important part in the food security of communities in the ASALs of Kenya. Lately, communities such as the Samburu in Northern Kenya, who are traditional cattle-keepers but with close association for a long time with several camel-keeping neighbours, have begun adopting camels as part of their livelihood diversification, in response to continued loss of their cattle as a result of drought, cattle raiding and diseases (Sperling, 1987; Stiles, 1987). It is estimated that there are about 2.9 million camels in Kenya (KBS, 2010), all being the one-humped type (*Camelus dromedarius*), and found mainly in the ASAL Counties. Isiolo County has about 39,084 camels and a human population of about 143,294 (KBS, 2010).

In northern Kenya, camels are traditionally reared under pastoral system, usually in communally owned rangelands, mainly by subsistence pastoralists. This system is characterized by low production inputs/investments, low productivity/output, seasonal migration as well as herd and household mobility in search of pastures, water and mineral licks, or when other conditions (e.g. inter clan feuds) necessitate movements. The mobility enables pastoralists to utilize rangeland resources more efficiently (Farah et al., 2004; Guliye et al., 2007). However, in the last decade or so, there has been an emerging trend in northern Kenya where camels are reared within the peri-urban areas of towns like Isiolo. The emergence of peri-urban camel production may have been initiated by market oriented entrepreneurs taking advantage of available market opportunities for camel products (e.g. milk) provided by consumers in towns.

Previous studies on camel production systems in northern Kenya concentrated only on pastoral system (Kaufmann, 1998; Noor, 1999; Farah et al., 2004) and there is little or no available information on the peri-urban camel production system in Kenya or elsewhere. The objective of the present study therefore, was to analyse the emerging peri-urban camel production around Isiolo town in Northern Kenya, in order to identify constraints and possible interventions to improved productivity. The traditional pastoral camel production widely practiced in Isiolo County was used as a reference in order to better understand the emerging peri-urban system. Information obtained would be useful

in planning and implementation of livestock-based livelihood support interventions in ASALs of northern Kenya.

Materials and Methods

Study area

The study was conducted in Isiolo County, which lies within the ASALs of northern Kenya (Figure 1). The County, located between Longitude 36°50' and 39°30' East and Latitudes 0°5' and 2° North, has a total area of 25,605 km^2. Most of the County is flat, low lying plains with altitudes ranging between 180 m above sea level at Lorian Swamp in the northern part and 1,000 m above sea level in the southern part. Volcanic hills formed as a result of volcanic activities of the now dormant Mount Kenya form the western part of the district. The County was selected for this study because of the presence of both peri-urban and pastoral camel production systems, and the existence of a thriving camel milk business in Isiolo town. There was no overlap between the peri-urban and pastoral study sites as they were far from each other.

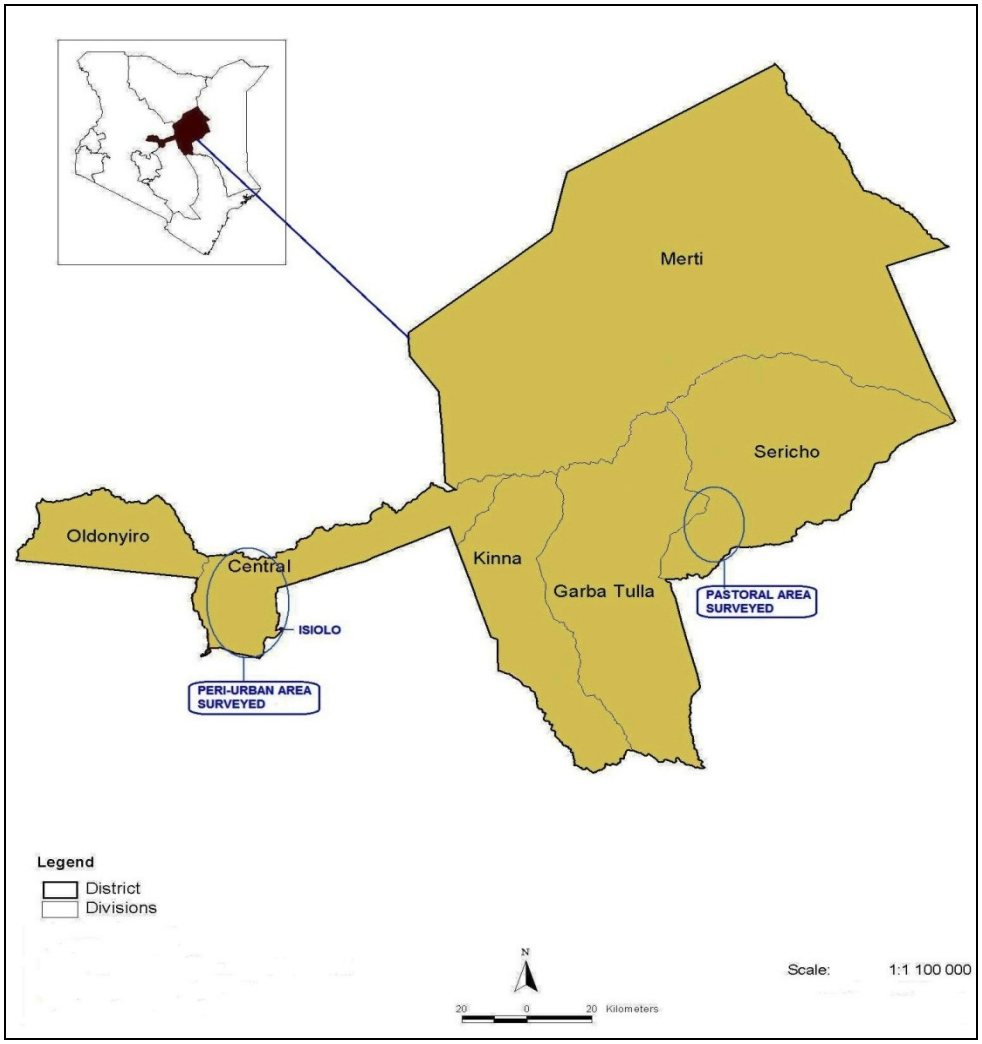

Figure 1. Map of Isiolo County (Kenya) showing the peri-urban and pastoral camel production study sites.

Isiolo County falls within three agro-climatic zones: i) semi-arid, occupying 5% of the area; ii) arid, occupying 30%; and iii) very arid, occupying 65% (Sombroek et al., 1982; Herlocker et al., 1993). The rainfall pattern is usually bimodal with two rainy seasons: long rains coming in late March to May, and short rains in November and December. However, rainfall is generally unpredictable and erratically distributed throughout the year. The climate of Isiolo town is semi-arid with an annual rainfall in the range of 400-600 mm (Herlocker et al., 1993). Rainfall in the rest of the County is below 350 mm per year. Frequent droughts that cause loss of livestock and sometimes human lives are a common occurrence. The County is hot throughout the year with mean annual temperatures ranging between 24^{o}C and 30^{o}C (Herlocker et al., 1993). Under these conditions, rain-fed crop farming is not feasible.

Data collection

Two cross-sectional surveys were conducted in February 2007 in Isiolo County, Kenya: the first within the peri-urban area of Isiolo town and the other in the rangelands where the pastoral system is practiced. The former represented peri-urban camel production, where milking herds are reared near urban centres with a lot of market integration through sale of camels and camel products (e.g. milk). The latter represented traditional camel production under a pastoral setting, where pastoralists rear their camels far from urban centres mainly for subsistence and they move with their herds in search of pasture, water and mineral licks within the rangelands. There is minimal market integration and access to services in the pastoral system. The two different systems were selected to enable comparative analysis in order to understand their characteristics, especially the peri-urban camel production system.

Due to the high mobility and scattered nature of camel herds, especially for the pastoral herds, sampling in both sites was based on accessibility and willingness to participate in the studies. There were 60 and 70 herders sampled in the peri-urban and pastoral areas, respectively. The individual herds formed the sampling units and the herd owners interviewed provided the primary data. Trained enumerators that spoke the language of the respondents and supervised by the authors conducted the surveys using questionnaires pre-tested on a small sample (10 respondents) of camel herders to test clarity of the questions. Information on the camel owners, evolution of Isiolo peri-urban camel production, relative importance of various livelihood sources, source of foundation camel herds and herd structures, camel feed resources, and camel production constraints and their coping strategies were collected.

A focus group discussion (FGD) was held in Isiolo town involving 50 participants to obtain additional information. The participants in the FGD included: camel producers (22), camel milk traders (10), representatives of government departments (10), non-governmental organizations (NGOs) (2), community based organizations (CBOs) (2), and local leaders (4). Camel producers and milk traders formed the majority (approx. 70%) of the participants. The participants provided information on the camel production systems in Isiolo County, especially on the evolution of the peri-urban

camel production, its constraints and coping strategies, and the marketing of camel milk.

Table 1. Characteristics of camel owners in peri-urban and pastoral production systems in Isiolo district, northern Kenya

Characteristic		Production system		Chi-square test	
		Peri-urban (n=60)	Pastoral (n=70)	$\chi 2$ - value	*p*-value
Gender	Male (%)	76.7	95.7	10.312	0.001
	Female (%)	23.3	4.3		
Education level	None (%)	63.3	85.7	12.913	0.005
	Primary (%)	23.3	14.3		
	Secondary (%)	8.3	0.0		
	Post secondary (%)	5.0	0.0		
Occupation	Livestock keeping (%)	83.3	100.0	12.639	0.002
	Business (%)	10.0	0.0		
	Formal employment (%)	6.7	0.0		

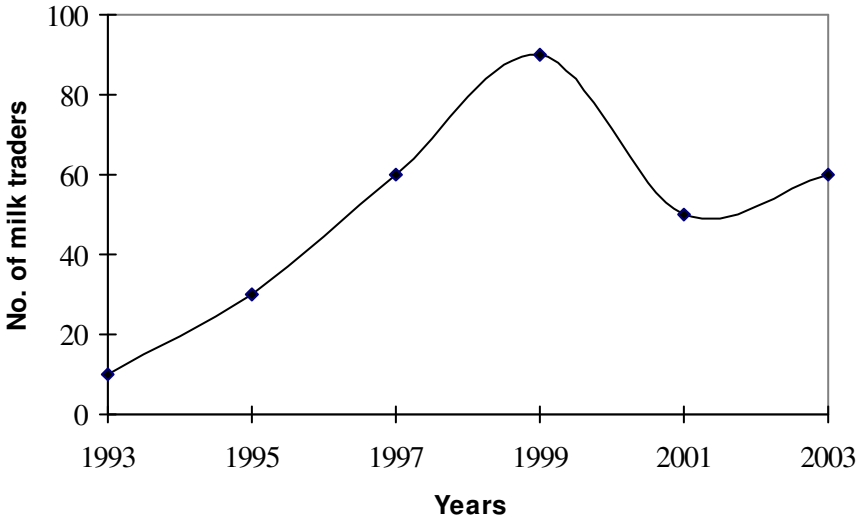

Figure 2. Trends in the growth of camel milk traders in Isiolo (Kenya), as suggested by 50 participants in a focus group discussion on the growth of milk traders.

Data analyses

Data collected through the questionnaires were analysed using the Statistical Package for Social Sciences (SPSS) version 12. Descriptive analysis of peri-urban and pastoral camel production systems provided a summary of the characteristics of camel owners, importance of various livelihood sources, evolution of Isiolo peri-urban camel production, camel herd structures, production constraints and coping strategies. Data with normal distributions were analysed using independent t-tests, while continuous data but lacking normal distributions were subjected to Mann-Whitney rank-sum tests (Mason and Lind, 1996; Petrie and Watson, 1999). Chi square tests were used to analyse discrete (categorical) data. The relative importance of the issues raised in the FGD was identified through ranking by the participants. Also, growth trends in camel milk traders in Isiolo (Kenya) were plotted using percentage growth as suggested by the participants in FGD.

Results

Characteristics of camel owners

The characteristics of the camel owners surveyed in the peri-urban and pastoral systems are presented in Table 1. Gender significantly (P<0.001) influenced ownership of camels in both systems. The majority of the camel owners in both production systems were males, however, there were almost 1.25 times more male camel owners in the pastoral system than in the peri-urban system. The number of female camel owners were much higher (almost 5.4 times) in the peri-urban than the pastoral production system. Most of the camel owners in both systems have no formal/secular education, although there were 1.35 times more camel owners with no formal/secular education in the pastoral system than the peri-urban system. However, some (13.3%) camel owners in the peri-urban system had at least a secondary level of education. The results also indicate livestock keeping as the only form of occupation in the pastoral system, whereas in the peri-urban system 16.7% of camel owners were engaged in alternative occupations (business and formal employment) in addition to livestock rearing.

Evolution of the Isiolo peri-urban camel production system

The emergence of the Isiolo peri-urban camel production system from subsistence pastoralism to the market-oriented milk production system has led to the emergence of traders engaged in camel milk business since 1993 (Figure 2). There was a general increase in the number of traders engaged in the camel milk business between Isiolo town and Nairobi city (Figure 2). However, the number of camel milk traders declined between 1999 and 2001, which was attributed to ethnic conflicts in the Isiolo area during that period.

Importance of various livelihood sources

The relative importance of livestock and non-livestock livelihood sources amongst peri-urban and pastoral camel keepers sampled in Isiolo County, is presented in Figure 3. Overall, camels ranked as the most important livelihood source in both systems, whereas non-livestock livelihood sources (business, crop farming and formal employment) ranked lowest. Comparisons amongst livestock within each of the two production systems indicate that camels and cattle ranked higher (P<0.05 and P<0.001,

respectively) as livelihood sources in the peri-urban system. Whereas small ruminants (sheep and goats) ranked higher (P<0.001) as a livelihood source in the pastoral system, and cattle ranked lower in the same system. The respondents rated the peri-urban production system as a better (P<0.01) business venture compared to the pastoral system. Crop farming and formal employment were regarded important livelihood sources in the peri-urban system, although their rating was much lower (Figure 3).

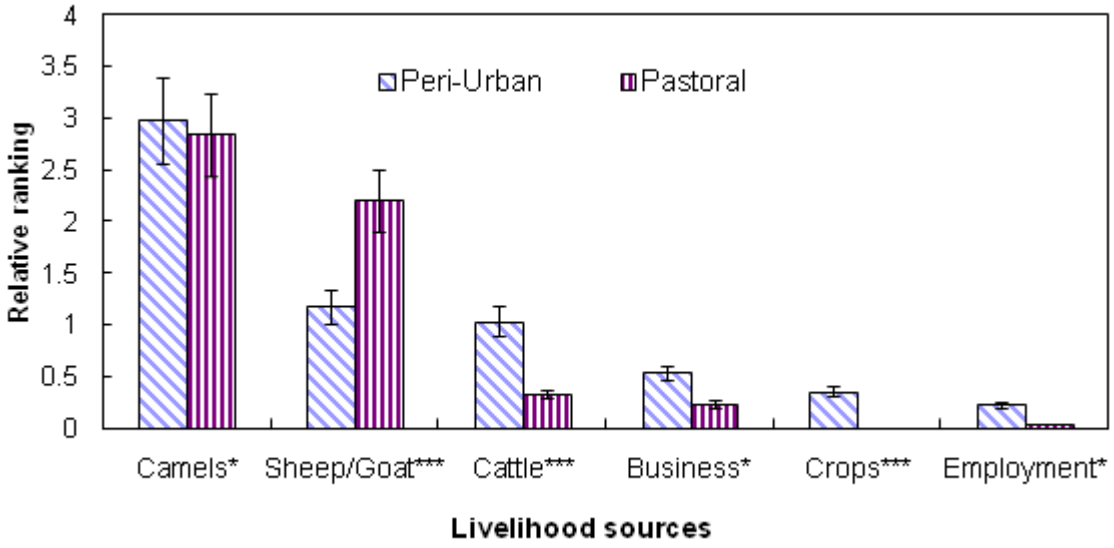

Figure 3. Ranked (0 = not important, 3 = very important) relative importance of livestock and non-livestock livelihood sources among camel keepers in Isiolo district, northern Kenya (*P<0.05; **P <0.01; ***P <0.001).

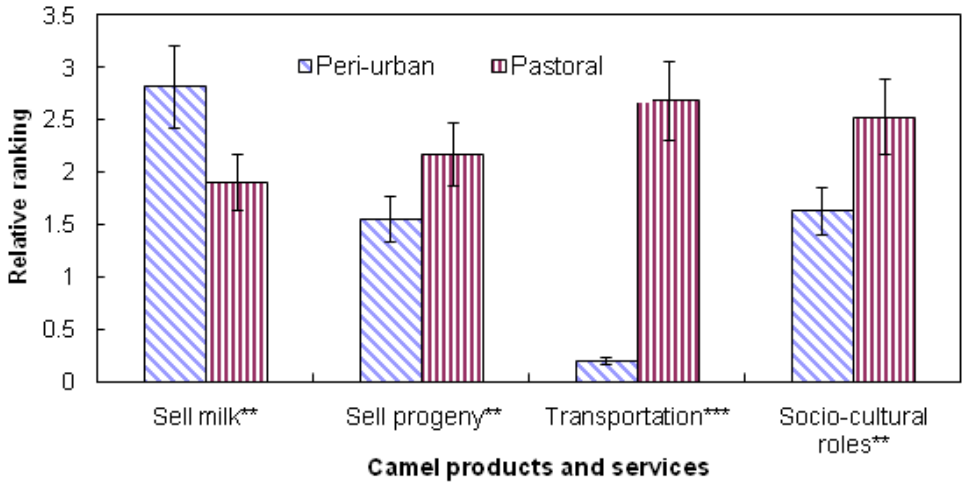

Figure 4. Ranked (0 = not important, 3 = very important) relative importance of the different camel products and services to the camel keepers in Isiolo district, Kenya. (**P<0.01; ***P <0.001).

The underlying reasons for keeping camels varied between the peri-urban and pastoral production systems. Figure 4 illustrates the relative importance of the different camel products and services to the camel keepers in Isiolo County. In the peri-urban system, milk for sale is more important (P<0.01), whereas sale of progenies (P<0.01), transportation (P<0.001) and socio-cultural roles (P<0.01) emerged as the important roles of camels in the pastoral system. The importance of camels for transportation is quite low in the peri-urban system compared to the pastoral system.

Source of foundation camel herds and herd structures

The sources of foundation camel herds in peri-urban and pastoral production systems of Isiolo County are given in Table 2. The majority of camel keepers (60% of the respondents) in the peri-urban system purchased their foundation stock. In contrast, camel herds in the pastoral production system are mainly built through inheritance, possibly reflecting adherence to tradition and less market integration. In terms of herd structures, there is a slightly higher proportion of breeding females (0.49 *vs* 0.48), though not significant, kept by producers in the peri-urban production system as compared to pastoral system (Figure 5). However, the proportion of breeding males in the pastoral system was higher (P<0.05) than in the peri-urban system. There were no significant (P>0.05) differences in the proportion of male calves, female calves, immature (weaned but not mature) males, and immature females in the two systems.

Table 2. Sources of foundation herds in peri-urban and pastoral systems of camel production in Isiolo district, northern Kenya

Source of foundation stock	Production system		Chi-square test	
	Peri-urban (n=60)	Pastoral (n=70)		
			$\chi 2$ - value	P-value
Inheritance (%)	26.7	81.4	39.46	0.000
Purchase (%)	60.0	14.3		
Inheritance and purchase (%)	13.3	4.3		

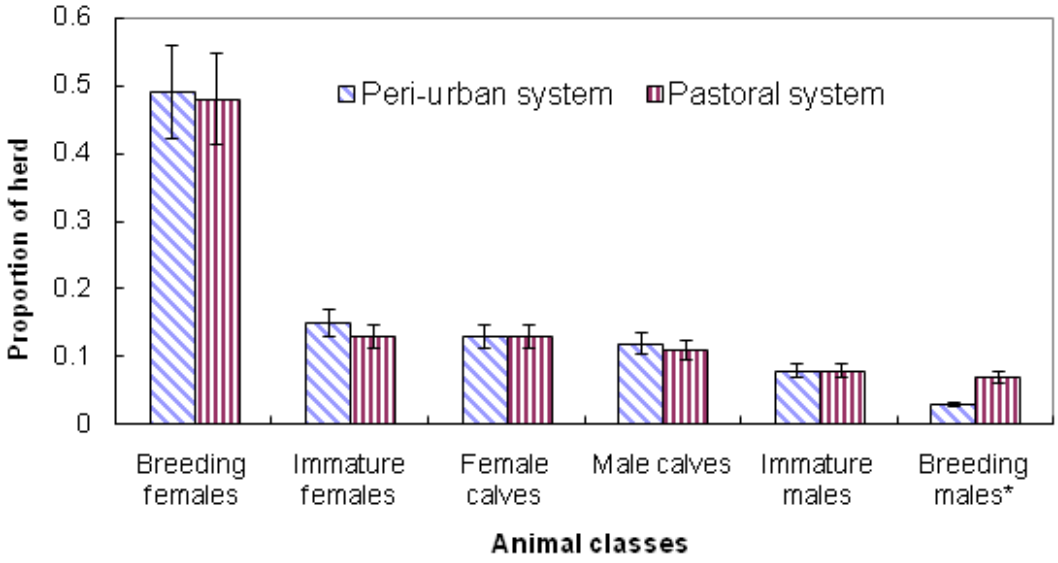

Figure 5. Proportion of the camel herd divided into the different animal classes in peri-urban and pastoral production systems in Isiolo district, northern Kenya (*p<0.05).

Camel production constraints and coping strategies

The major constraints facing camel producers in Isiolo County of northern Kenya, ranked in order of importance by participants in the FGD were: camel diseases, inadequate feed resources and milk spoilage (Table 3). The coping strategies to these constraints suggested by the participants in the FGD are also given in Table 3.

Camel diseases

Camel diseases were ranked as the most important constraint facing camel producers in Isiolo County (Table 3). Some of the camel diseases frequently mentioned by camel keepers in the district are presented in Table 4. Trypanosomiasis and haemorrhagic septicaemia were key camel diseases of concern. Participants in the FGD indicated that most veterinarians in the district are less conversant with camel diseases and are therefore not able to provide appropriate and reliable clinical services to camel producers.

Feed resources

The relative importance of various forage categories as feed for camels in peri-urban and pastoral production systems in Isiolo County is presented in Figure 6. Browse forages are important camel feed resources in both peri-urban and pastoral production systems. However, the relative importance of grasses was significantly different (P<0.05) between the pastoral and peri-urban camel production systems. In addition, *Euphorbia tirucalli,* a succulent plant grown as a living fence that is not a traditional camel forage, has become an important alternative forage for feeding camels in the peri-urban system, especially during periods of severe feed shortage (Figure 6).

Table 3. Major constraints facing camel producers in Isiolo district (northern Kenya) ranked in order of importance by participants in a focus group discussion, and coping strategies used.

Rank	Problem/constraint	Coping strategies
First	Camel diseases	• Use of traditional treatments, and sometimes use of self prescribed veterinary drugs. • Occasional disease diagnosis through blood sample analysis done in distant labs e.g. in Nairobi. • Occasional vaccinations. • Use of community based animal health workers (CBAHW), due to limited animal health service providers.
Second	Inadequate feed resources	• Herd splitting (non-lactating camels taken to distant pastures – *forra* herds). • Feeding camels on *Euphorbia tirucalli* plant. • Providing security to enable the *forra* herds to exploit distant pastures.
Third	Milk spoilage	• Boiling of overnight milk. • Use of overnight cooling facilities only available in Isiolo town. • Washing of plastic containers with hot water. • Use of metallic cans by a few milk producers.

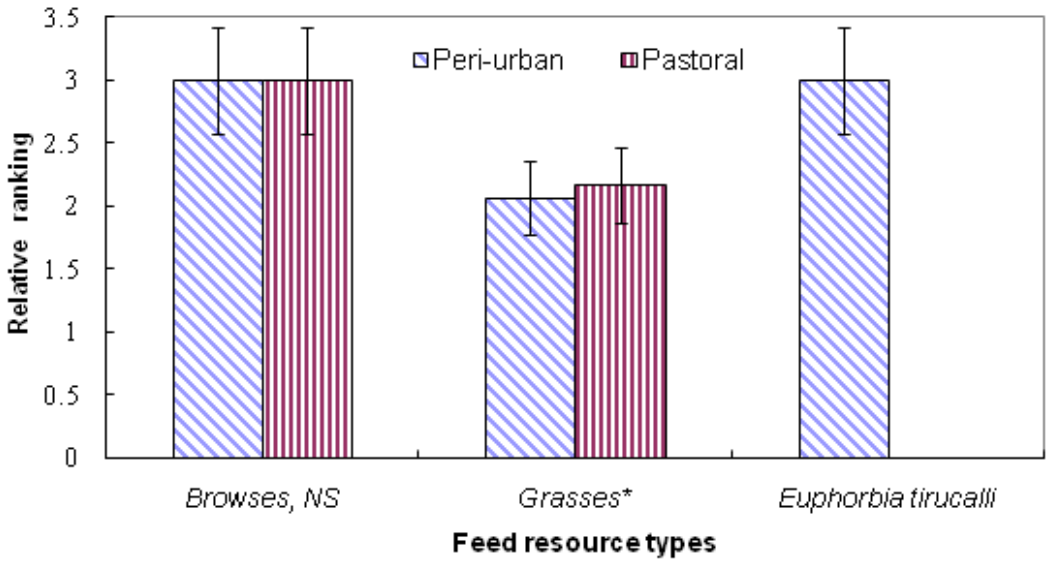

Figure 6. Ranked (0 = not important, 3 = very important) relative importance of camel feed resource types in peri-urban and pastoral production systems in Isiolo district, Kenya (**P*<0.05; NS – not significant).

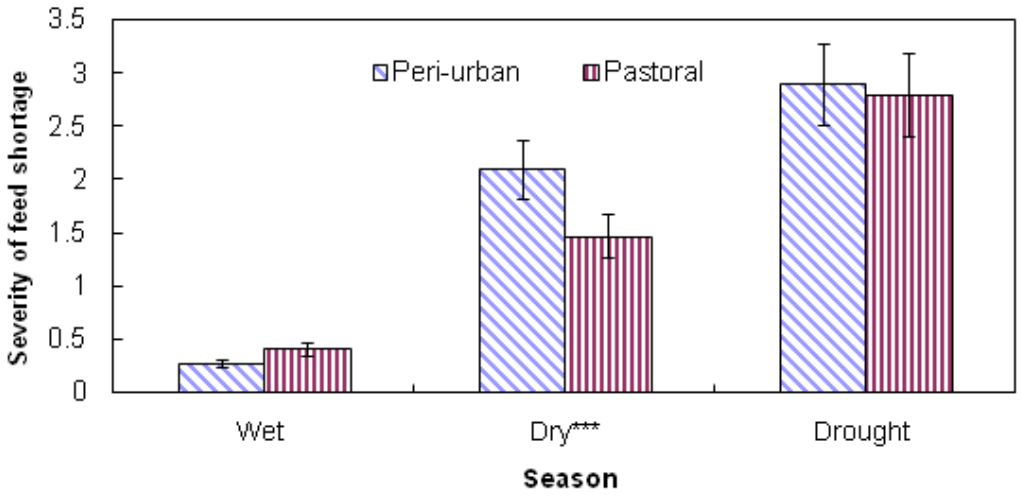

Figure 7. Ranked (0 = not severe; 3 = very severe) severity of feed shortages experienced in different seasons by camel keepers in Isiolo district, northern Kenya (****P*<0.001); Wet season = usually March to May, and November to December; Dry season = usually January to February, and June to October; Drought = months in the year when there is drought beyond the usual dry season period.

The camel keepers in both peri-urban and pastoral production systems of Isiolo County face feed shortages during the dry and drought periods of the year (Table 3; Figure 7). However, the severity of feed shortages in the dry season was significantly higher (P<0.001) in the peri-urban production system. The strategies commonly used for coping with periods of feed shortages by the camel keepers in both production systems are to send camels (especially dry herds) to "*forra*" (distant pastures) and to prolong their daily grazing hours.

Milk spoilage

The third most important challenge facing camel keepers in Isiolo County, especially the peri-urban producers, was milk spoilage (Table 3). Availability of adequate clean water in areas where camels are kept is a major constraint to clean milk production, and greatly contributes to milk spoilage. The most commonly used containers for milk storage and transportation from herds to markets are plastic jericans. These containers are not easy to clean and therefore cause milk spoilage, despite washing with hot water. The use of overnight cooling facilities is limited to a few camel keepers who are able to bring evening milk to Isiolo town where such facilities are available.

Table 4. Important diseases of camels in Isiolo district, northern Kenya.

Disease		Production system	
Common name	Vernacular name (Borana/Somali)	Peri-urban (%)	Pastoral (%)
Trypanosomosis	*Dukan/Gandi*	30.0	30.5
Haemorrhagic septicaemia	*Khandich/Qarar*	11.1	21.4
Anthrax	*Chit/Kut*	-	11.0
Mange (Mites, Scabies)	*Chito/A'ddo*	7.2	9.1
Pneumonia/Camel cough	*Dugud/Hergeb*	25.0	7.1
Camel pox	*Bagga/Furuq*	-	3.3
Paralysis/Brain disease	*Shimbir/Gudan*	8.9	-
Skin necrosis	*Dulla*	3.9	-
Others minor diseases		13.9	17.6

Discussion

Camels, compared to other livestock, have received less attention in terms of research and development in Kenya. Perhaps, this may be due to the perceived lack of importance as food animal by policy makers and development agencies. However, in the last decade or so there is increased recognition of the important role played by camels in contributing to the food security of Kenya's ASALs. Their importance may be due to the increased frequency of droughts in the country as a result of climate change and the ability of camels to survive better than other livestock (Yagil, 1985; Rutagwenda et al., 1989; Schwartz, 1992). The aim of the present study was to gain an understanding of the emerging peri-urban camel production system around Isiolo town, highlighting differences from the traditional pastoral camel production system. These findings are discussed below.

Characteristics of camel owners

The observation in the present study where gender significantly (P<0.001) influenced camel ownership in both systems, in favour of males, conforms to the situation in most pastoral communities, where men are regarded as heads of households and owners of livestock (Schneider, 1979). Men perhaps own more camels as they shoulder more household responsibilities. However, between the two systems, there were more females owning camels in the peri-urban production system (Table 1), indicating involvement of women in camel keeping and increasing empowerment of women in Kenya. The rearing of camels in close proximity to urban towns like Isiolo, where services are easily accessible coupled with the possibility of getting income from the sale of camel milk may have encouraged women to rear camels.

The lifestyle of most pastoralists, whole livelihood revolves around livestock, involves regular movements in the rangelands in search of pastures and water for their animals. Such lifestyle is not conducive for formal education, which requires a sedentary lifestyle where children can go to school in a fixed location. This may explain the high proportion (>80%) of camel keepers in pastoral system with no formal education (Table 1). Nonetheless, the high percentage (>60%) of camel keepers with no formal education observed in the peri-urban system, despite close proximity to Isiolo town, suggests they may have been previously brought up in the pastoral system. However, in the peri-urban system there were some respondents, with at least primary level education, engaged in camel rearing as an economic activity indicating that educated people in the town are getting involved in peri-urban camel production.

Livestock keeping appears to be the main form of occupation available to pastoralists in pastoral production systems (Table 1), camels being amongst the most important animals reared by these pastoralists. This observation indicates, under the circumstances of the hash environmental conditions of ASALs, livestock keeping is the most suitable form of land use. It also indicates lack of suitable alternative livelihood sources available to the pastoralists in ASALs. However, few other alternative forms of occupation, such as formal employment or business ventures, are available to peri-urban camel keepers around Isiolo town. It is probable that peri-urban

camel keepers have town based occupations and they engage in camel keeping as a secondary activity to earn extra income.

Evolution of the Isiolo peri-urban camel production system

The emergence of Isiolo peri-urban camel production may have begun in the early 1990s (Figure 2), in response to market demands for camel milk and has rapidly increased since then. Three factors may have contributed to the emergence of market-oriented peri-urban camel milk production around Isiolo. Firstly, there may have been progressive sedentarization of pastoral communities with a camel keeping background in and around Isiolo town since 1972. Secondly, the emergence of a niche market for camel milk in Nairobi (Eastleigh area) following the influx of Somali refugees, with strong traditions of camel milk consumption, following the collapse of the neighbouring Somali government in 1991 and the subsequent instability that followed. Thirdly, the presence of a reliable (tarmac) road and daily means of public transport (i.e. buses) for transporting milk from Isiolo town to the main camel milk market in Nairobi. The settling by formerly mobile pastoral populations near urban towns has been reported to be occurring rapidly throughout East Africa, in response to drought-induced livestock losses, increased involvement in market economies and violence of livestock raiding and ethnic conflict (Fratkin, 2001; McCabe, 2004).

In addition to the influx of Somali refugees into Nairobi, progressive migration of people from a camel keeping background (i.e. Kenyan Somalis, Gabra and Rendille tribes) into urban cities like Nairobi in search of business and employment opportunities (Simpkin et al., 1996) also contributed to the demand and growth of the market for camel milk. These newly urbanized people from camel keeping communities have a strong tradition of camel milk consumption, perhaps driven by their belief that camel milk has medicinal values, leading to the rapid increase in the demand for camel milk in Nairobi. Consequently, there has been an increase in the number of peri-urban camel producers around Isiolo, which could have attracted camel milk traders transporting milk to the Nairobi market since 1993 (Figure 2). However, the decline in the number of camel milk traders between 1999 and 2001 (Figure 2), could have been due to ethnic conflicts in Isiolo which led to many camel producers moving away from the peri-urban area. As soon as relative peace returned, there was renewed growth in the number of camel milk traders. Peaceful coexistence amongst communities in Isiolo is not only a great incentive for the growth of the peri-urban camel production but also for the overall camel milk business. The increased commercialization of camel milk in urban niche markets observed in Kenya in the present study, is similar to trends reported in neighbouring countries like Somalia (Herren, 1990; Farah et al., 2007) and Ethiopia (Seifu, 2007), as well as in other African countries such as Djibouti, Mauritania, Morocco and Sudan (Wilson, 1998). Camels are, therefore, slowly but steadily gaining significance as a dairy animal for commercial milk production.

Importance of various livelihood sources

The relative importance attached to camels in both peri-urban and pastoral production systems as a livelihood source (Figure 3) is in agreement with previous

reports (Yagil, 1986; Stiles, 1987; Guliye et al. 2007). The importance of camels may be attributed to their ability to survive the harsh environmental conditions in ASALs (Yagil, 1985; Rutagwenda et al., 1989; Schwartz, 1992; Guliye et al., 2007), while providing food by way of milk and meat. The prospect of better returns from the sale of milk makes camel keeping a better livelihood source in the peri-urban production system of Isiolo compared to the pastoral system. Goats are, however, regarded as the second most important livestock species, after camels, in terms of livelihood support amongst camel keeping communities, especially those in pastoral systems (Figure 3). This may be due to the ability of goats to browse and select a diet of higher nutritive value than sheep and cattle, especially in the dry season (Lechner-Doll et al., 1990), thus enabling them to survive better in ASALs. Businesses, formal employment and crop farming were rated less important sources of livelihoods by the camel keepers, especially those in the pastoral system, because the areas they live are generally less developed with little business or employment opportunities, relative to the rest of the country, and receive little rainfall to support crop farming.

The camel plays varied roles in the pastoral and peri-urban production systems of Isiolo district (Figure 4). In the peri-urban system, the sale of camel milk is an important economic activity, attributable to the prospect of better returns arising from the increasing demand for camel milk in urban markets like Nairobi. With milk for sale being the most important production function, the results demonstrate a peri-urban camel system, as a market oriented production system, reflect the changing roles of camels with progressive market integration. However, in the pastoral system, camels are mainly kept for subsistence purposes and there is less emphasis on milk marketing.

The lesser importance attached to the sale of progeny animals (especially females) in the peri-urban camel production system indicates the need to rear replacement stock in order to save on the cost of buying breeding females. In the case of the pastoral system, the sale of progeny animals, probably to peri-urban camel keepers, is likely to be an important source of income. Besides, camels (notably males) are an important means of transport in the pastoral system (Figure 4), in agreement with the earlier report by Guliye et al. (2007). Pastoral families use camels to carry their makeshift houses and other belongings as they move within the rangelands in search of pastures and water for their animals. In contrast, the homesteads of peri-urban camel keepers are usually around settlements like Isiolo town and are hardly mobile, hence there is no need for transportation using male camels. However, the camel herds, often herded by hired young men, move within the peri-urban area of Isiolo.

The importance attached to the socio-cultural roles of camels in both systems in the present study, more so in pastoral production (Figure 4), confirms previous observations made by Guliye et al. (2007). Camels play an important role in traditional social relations, such as payment of dowry, religious ceremonies and compensation of injured parties in clan feuds (Guliye et al., 2007). Besides, camel ownership (in terms of herd size) is an indication of social status in camel keeping communities.

Source of foundation camel herds and herd structures

Unlike in the pastoral production system where most (>80%) camel keepers obtain their foundation stock through inheritance, 60% of the camel keepers in the peri-urban system purchased their foundation herd (Table 2). The prospects of income generation through the sale of camel milk may be the main reason for the purchase of foundation camel herds amongst camel keepers in the Isiolo peri-urban production system. Besides, the emphasis on marketed milk (Figure 4) suggests transformation from subsistence to market-oriented production in the peri-urban system. Also, the significantly higher (P<0.05) proportion of breeding females (0.55 vs 0.48) in the peri-urban system compared to pastoral (Figure 5), indicates the need for more breeding animals in lactation to provide milk for sale. In contrast, herds in the pastoral production system are built through inheritance, perhaps as a reflection of a production system that is based on subsistence and adherence to tradition, with less attention given to market integration. The findings indicate that the peri-urban system is more focused towards commercialization i.e. milk production for sale.

Camel production constraints and coping strategies

Camel diseases

The findings of the present study indicating diseases are important constraints to camel production in Isiolo County is in agreement with observations reported in other parts of northern Kenya (Rutagwenda, 1983; Dioli and Stimmelmayr, 1992; Noor, 1999; Ngaira et al., 2003) and in Ethiopia (Baars, 2000). The disease problem in camels is compounded by severe shortage of qualified animal health workers (especially veterinarians) and the inability of most available workers to provide reliable treatment services because of their limited understanding of camel diseases. Thus, any mitigation approaches to control camel diseases should include training of animal health workers on camel diseases, to enable them carry out correct disease diagnosis so as to offer appropriate treatment. To overcome disease challenges, camel producers either engage the services of community based animal health workers if available, or use traditional treatment methods. Others buy veterinary drugs from chemists and administer the drugs themselves. However, this practice has the risk of abuse and misuse of drugs in the treatment of camels, without regard to disease diagnosis, dosage and potency as reported previously by Noor (1999). In order to enhance the development of the camel sector in northern Kenya, there is an urgent need to improve animal health services, through recruitment of qualified personnel and establishment of veterinary diagnostic facilities, strategically located within camel producing areas to facilitate rapid diagnosis and treatment of diseases.

Feed resources

The present finding where browse forages are important camel feed resource in both peri-urban and pastoral production systems of Isiolo County (Figure 6) is in line with previous observations (Rutagwenda et al., 1989). Comparative studies by Rutagwenda et al. (1989) on the dietary preferences of indigenous camels, cattle, sheep and goats in a semi-arid thorn-bush savannah in northern Kenya established that

cattle and sheep preferred vegetation at ground level, mostly consisting of grasses, herbs and small shrubs. On the other hand, goats browsed up to 2 meters above the ground (mainly on herbs and small shrubs), whereas camels were capable of reaching plants up to a height of 3 meters, mostly deep rooted large bushes and trees. Thus, during the dry season when leaves of big trees may be the only green vegetation available, camels and to some extent goats benefit greatly compared to cattle and sheep. However, camels are quite capable of feeding on grasses at ground level, as shown by the findings of the present study, possibly as an adaptation to feed shortages. The importance of grasses as feed resources for camels in the peri-urban production system compared to the pastoral system, may be attributed to the high concentration of camels in the peri-urban system, leading to over-exploitation of available browse forages thus making camels to rely on grasses.

Although camel keepers in both peri-urban and pastoral systems of Isiolo County face feed shortages during dry and drought seasons (Figure 7), the severity in the dry season is significantly higher ($P<0.001$) in the peri-urban system. This may be due to the higher concentration of camels within Isiolo peri-urban area, exerting enormous pressure on feed resources. The feed shortage experienced during the dry and drought periods compel many camel owners to move their herds to Isiolo town so that their animals can browse on *Euphorbia tirucalli*, a succulent evergreen forage usually used as live fence. *Euphorbia tirucalli* is not a traditional camel forage but has become an important feed resource in Isiolo peri-urban camel production (Figure 6), such that camel owners pay the Euphorbia owners so that their camels can browse, especially during dry and drought periods when feed shortages are severe. Although it is used as an alternative feed resource, its nutritive value and possible effects on camel products (such as milk and meat) are unknown. In contrast, camel keepers in the pastoral system, where milk marketing is not a priority production objective, exploit distant forages through seasonal mobility within the rangelands and probably suffer less from the effects of droughts that cause forage shortages. However, such flexibility is not available in the peri-urban system as camel herds have to stay in close proximity to the milk market in Isiolo town.

Herd splitting and prolonged daily grazing hours are other strategies used by camel producers in both production systems, to cope with feed shortages (Figure 6). The practice of herd splitting, where dry herds are sent to access distant pastures (usually referred to as "*forra*"), is more prominent in the pastoral system, perhaps due to the ability of camel herders to move their animals within the expansive rangelands. Herd splitting as a mitigation strategy to overcome inadequate forage supply has also been reported amongst camel keepers in Moyale, northern Kenya (Noor, 1999; Farah et al., 2004). The use of cultivated forages, crop residues and supplementation with commercial feeds is not practiced in camel production systems of Isiolo County, similar to previous observations reported from neighbouring Ethiopia (Baars, 2000). Availing appropriate and affordable camel feeding interventions to mitigate feed shortage in dry and drought periods, especially in Isiolo peri-urban camel

production system, would help sustain milk output and household incomes.

Milk spoilage

The problem of milk spoilage is of great concern to camel producers in the peri-urban production system of Isiolo, as it causes direct economic loss to both producers and camel milk traders. Camel milk traders buy only fresh milk from producers, since most camel milk consumers prefer fresh milk (i.e. not fermented) (Farah et al., 2007; Seifu, 2007). Fermented camel milk (*susac*) is sometimes sold at almost half the price of fresh milk, and therefore does not bring as much income as fresh milk. The problem of milk spoilage may be as a result of: inadequate clean water in areas where camels are reared, use of inappropriate containers (such as plastic jericans) for milk storage and transportation, and lack of understanding of the principles of clean milk production by camel keepers. These challenges can be overcome through provision of water sources within camel keeping areas, provision of appropriate milk containers, and educating camel herders on clean milk production. Such interventions will not only reduce post-production losses but also provide safe and quality camel milk to consumers.

Conclusions

Camels are traditionally reared under pastoral production system, mainly for subsistence, in the ASALs of northern Kenya. However, camel keeping is slowly but steadily gaining significance as a dairy animal for commercial milk production. In the last decade, there is an emergence of market-oriented peri-urban camel production around towns such as Isiolo, in response to increased demands for camel milk in Nairobi. However, in terms of camel ownership, there is a gender difference with the majority of the camel keepers in both peri-urban and pastoral production systems of Isiolo being males, and most with no formal/secular education. The majority of the camel keepers in Isiolo peri-urban production system built their herds through purchase of foundation stock, whereas camel herds in the pastoral system were mainly built through inheritance. With regards to livelihood support, camels ranked as the most important in both systems, whereas non-livestock livelihood sources (e.g. crop farming and formal employment) ranked lowest.

The major constraints facing camel producers in Isiolo district are camel diseases, inadequate feed resources and milk spoilage. To overcome the disease problem, camel producers either engage the services of community based animal health workers or use traditional treatment methods. The strategies adopted by camel keepers to cope with the problem of inadequate feeds, commonly experienced during dry seasons, are use of *Euphorbia tirucalli* as forage for camels, herd splitting and prolonged daily grazing hours. Appropriate and affordable camel supplementary feeding interventions, to mitigate feed shortage in dry and drought periods, would help sustain milk output and household incomes. The problem of milk spoilage, which causes direct economic loss to both producers and camel milk traders, can be overcome, at least in part, by providing water sources within camel keeping areas, use of appropriate milk containers for storage and transportation, and educating camel herders on clean milk production.

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