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Performance of dairy goats in selected regions of Botswana and the effect of improved management practices on milk yield and composition

By

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A Dissertation submitted in partial fulfilment for Masters of Science Degree in Animal Science (Animal Management System)

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DECLARATIONS

The research described in this Dissertation was carried out in the Department of Animal Science and Production, Botswana College of Agriculture, Gaborone under the supervision of Dr G.S Mpapho, Prof S.J Nsoso, Prof J.M Kamau, and Dr W. Mahabile.

This is to declare that this Dissertation is the result of my own investigation and had not been presented in any previous application for a degree. All sources of information are shown in the text and listed in the references and all assistance by others has been duly acknowledged.

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Kealeboga Dipheko

November 2015

APPROVAL

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DEDICATIONS

I dedicate this work to my son, Prince, whose smile really gave me the strength and inspiration throughout the tough and straining period of this research work. Daddy is grateful to you my boy!!!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%	Percentage
2x	Twice Daily milking
3x	Three times daily milking
ADF	Acid Detergent Fibre
APRRD	Animal Production and Range Research Division
BCA	Botswana College of Agriculture
BCU	Botswana Cooperative Union
BNVL	Botswana National Veterinary Laboratory
BOS	Botswana Standards
Ca	Calcium
CEDA	Citizen Enterprenuership Development Agency
CMT	California Mastitis Test
CP	Crude Protein
DAR	Department of Agricultural Research
DM	Dry Matter
DMI	Dry Matter Intake
ECM	Energy Corrected Milk
EE	Energy Efficiency
EE	Ether Extract
FAO	Food and Agriculture Organisation
FAOSTAT	Food and Agriculture Organisation Statistics
FAP	Financial Assistance Policy
FCM	Fat Corrected Milk

FE	Fat Efficiency
FFTC	Foundation For The Carolinas
ISO	International Standards Organisation
Kg/d	Kilogramme per day
LIMID	Livestock Integrated Management and Infrastructure Development
LSD	Least Significant Difference
Mcal	Mega Calorie
N	Nitrogen
NAMPAADD	National Master Plan for Arable Agriculture and Dairy Development
NARO	National Agricultural Research Organisation
NDF	Neutral Detergent Fibre
NEFA	Non-Esterified Fatty Acids
Nel	Net energy for lactation
NRC	National Research Council
P	Phosphorus
SAS	Statistical Analysis Software
SCC	Somatic Cell Count
SCS	Somatic Cell Score
SEM	Standard Error of Means
SLOCA	Services to Livestock Owners in Communal Areas
SPSS	Statistical Package for Social Sciences
TMR	Total Mixed Ration

CHAPTER ONE

1.0. General Abstract

In Botswana milk production generally come from dairy cattle breeds, but there are some goat breeds that have the genetic potential for producing large quantities of milk. This dissertation was a record of two studies on Performances of dairy goats in selected regions of Botswana and the effect of improved management practices on milk yield and composition. The first study was a survey that identified the current situation of smallholder dairy goat production in Central, Kgatleng, and Kweneng districts of Botswana. Data were collected through a survey using structured questionnaires that were administered face to face to the identified dairy goat farm owners in Central, Kgatleng, and Kweneng districts of Botswana. Data were analysed using the Statistical Package for Social Sciences software. Dairy goat production was dominated by male farmers of which the majority 75% (9/12) had less than five years experience keeping dairy goats. The common dairy goat breeds kept by farmers were the Saanen, Crosses, Toggenburg and British Alpine. All the flocks (100%) were managed in a semi-intensive production system and were estimated to produce on average of 3 kg per day milk per goat at peak of lactation. Milk yield was estimated only at peak of lactation because farmers were not regularly measuring milk yield throughout the whole lactation period, they were only using the highest milk production estimates of each goat. The major challenges that dairy goat farmers faced included lack of available breeding stock, insufficient feeds and failure of the exotic breeds to acclimatize effectively to local climatic conditions. However, farmers believed that there was potential for growth of the dairy goat industry through dairy goat stud breeding, and fodder production particularly lucerne and lablab forages. In an attempt to motivate farmers to venture into dairy goat production, the second study was on-station experiment that determined the effects of feeding lucerne and lablab total mixed rations (TMR) and milking frequency on milk production and milk composition of mid-lactation Saanen dairy goats managed under an intensive system. Twenty eight lactating Saanen goats were

allocated to a 2 x 2 factorial arrangement in Randomized Complete Block Design for a period of seventy (70) days. Data were analysed by General Linear Model procedures in Statistical Analysis System. Goats fed the lucerne ration produced significantly higher average milk yields (2.51±0.067 vs 2.21±0.067 kg/d; P=0.0016), had higher DMI (2.49±0.067 vs 2.19±0.067 kg/d; P=0.0016) and 4% FCM (2.15±0.049 vs 1.84±0.049 kg/d; P<0.0001) than goats that were fed the lablab ration respectively. Milk yield (2.65±0.108 vs 2.10±0.108 kg/d; P<0.0001), DMI (2.60±0.107vs 2.07±0.107 kg/d; P<0.0001), 4% FCM (2.18±0.089 vs 1.81± 0.089 kg/d; P<0.0001) were significantly higher in goats that were milked twice a day than goats that were milked three times a day, respectively. Most of the farmers kept dairy goats for household milk consumption with a few selling the surplus milk. Regular milking and feeding high quality total mixed rations to dairy goats increased daily flock milk yield. Therefore, local dairy goat farmers should be encouraged to utilize affordable quality forages to feed their animals for increased milk production and improve their management.

Key words: Challenges, Dairy goats, feeding, milk production, opportunities

1.1. General Introduction

Milk production in Botswana is based on using exotic dairy cattle breeds and their crosses, despite many advantages in the use of goats rather than cows for subsistence milk production (Donkin, 1997; Kibuuka, 2011). For example, the increasing human population which is leading to increased land requirement pressure and smaller land sizes and inconsistent weather conditions may not support dairy cattle; making the dairy goat a better option, and a good pathway out of poverty for rural household's dwellers (Devendra, 1988). Their adaptive features such as feeding behaviour, disease and heat tolerance enables goats to effectively cope with the stressful nature of the vast marginal lands of Botswana (Katongole *et al*., 1994). Goats can survive under harsh environmental conditions; as a result they are the least likely ruminant animals to die from drought (Devendra, 1988).

Some goat breeds have potential for milk production and they are kept primarily for milk production (Donkin, 1997). Dairy goats can be reared in urban and peri-urban areas because the faecal consistence (pellets) is easier to handle and dispose than the bulky cow dung. The setting up of a dairy goat enterprise entails lower capital investment concurrent with lower risks (Kibuuka, 2011). They can also easily acclimatize to intensive production systems, and convert feed into highly nutritious milk very efficiently (Ogola and Kosgey, 2012). Goat milk has been shown to have a better role to play in human nutrition and medicine than cow milk owing to its composition (Adogla-Bessa and Aganga, 2000). Due to its "therapeutic properties", goat milk can be recommended in cases of dyspepsia, peptic ulcer, and to those intolerant/ allergic to cow milk especially infants and growing children (Kipserem *et al.*, 2011).

According to Mpapho (2010) milk production from goats by farmers in Botswana would not only reduce the high importation of milk but would increase their household income from its sales. It will improve nutritional status of farmers since it is rich in nutritive components essential for human nutrition. However, in Botswana dairy goat milk production has not gained much popularity due to issues perceived as lack of information on production, marketing and consumption (Mpapho, 2010). Farmers in Botswana are increasingly turning to goat rearing as a means to improve their welfare, increase household income, as well as commercial benefits from goat products (Moreki *et al*., 2011). Milk production, research, development and milk production improvement schemes from indigenous and exotic dairy goats reared by farmers under extensive production system remain stagnant (Mpapho, 2010). There is less published technical and scientific information available on the milk production of local, exotic and cross-breeds goats in Botswana despite having about 3.5 million goats in Botswana which are not kept for milk production and over 90% are managed extensively (Ministry of Agriculture, 2014; Mpapho, 2010).

1.2. Overall Objectives

The objectives of the study were to:

1.2.1. Determine the current situation of smallholder dairy goat production in Central, Kgatleng, and Kweneng districts of Botswana

1.2.2. Determine the effects of feeding lucerne and lablab total mixed rations (TMR) and milking frequency on milk yield and composition of mid-lactation Saanen dairy goats managed under an intensive system

CHAPTER TWO

2.0. Literature review

2.1. Overview of dairy goat production

Donkin and Boyazoglu (2001) indicated that as the population in Southern Africa continues to grow, milk will become more important as a source of high quality protein to reduce malnutrition, especially in children. In Africa, goat milk consumption has been said to increase in developing countries, where there is a marked shift from rural areas to urban centres (Leeuw *et al*., 1991). The increase in human population pressure and the ensuing land demarcation will stimulate use of dairy goats in rural development efforts which were previously ignored in favour of cattle (Ogola *et al.*, 2010). Milk production from dairy goats requires low investments such as land and labour as compared to cattle. However, these factors of production are not within the reach of most local farmers who are resource-limited and lack basic skills (Norris *et al*., 2011).

In Kenya, FARM–Africa which is a non-governmental organization, implemented a community-based dairy goat multiplication programme using exotic breeds (Saanen, British Alpine, Anglo-Nubian and Toggenburg) to improve the nutrition and incomes of rural households farmers (Donkin and Boyazoglu, 2001). The aims of the programme were to ensure a sustainable spread of dairy goats in the communities involved using a "pass-on" model contract and to impart dairy entrepreneurial skills to the farmers. The "pass-on" contract model used in East Africa required a beneficiary of a doe to pay in-kind by giving out the first two female offspring free to the next listed beneficiary who will in turn do the same (Ogola *et al*., 2010). The adoption of this practice in Botswana will help farmers recognize the importance of dairy goats to their daily welfare and household income because they will have an exposure to the daily management and production practices of dairy goats.

According to the Ministry of Agriculture Annual Report (2014), in Botswana there were 2.4 million goats. These statistics do not include dairy goats. Lack of statistics of dairy goats is due to the fact that a management system of small-scale household dairy production is not well studied in Botswana. Indigenous goats in Botswana are mainly kept for meat production with some farmers milking them only for household consumption.

2.2. Goat milk composition and quality

Goat milk is appreciated by consumers in view of its higher digestibility and tolerability when compared to other types of milk consumed by human (Pisanu *et al*., 2012). Dairy goat milk is typically sold as whole milk or processed to make cheese, yoghurt, fermented milk, evaporated milk or dried milk products (Bruhn, 1996). Fat content and composition are the key factors which determine milk and cheese attributes, therefore, milk with a low fat percentage is associated with a reduced cheese yield and firmness as well as negative effects on flavour and colour (Amills *et al*., 2012). The composition of the milk produced by a given breed depends on the lactation state and feeding (Ceballos *et al*., 2009).

Addass *et al*. (2013) investigated the effect of breed, stage of lactation and parity on milk composition of Red Sokoto, Sahel goat and West African dwarf in Mubi. Highest protein content was observed on Red Sokoto and least on West African Dwarf. Fat content was the highest in Sahel goat and least in Red Sokoto while lactose content was the highest in Red Sokoto and least (on West African Dwarf goat. Stage of lactation also influenced protein, fat and lactose level of milk with highest contents in early lactation stage. Least content of protein, fat and lactose were noted at the end of lactation.

Malau-Aduli *et al*., (2003) investigated variations in milk yield, milk composition, nutrient intake and digestibility of the goats in Nigeria fed crop-residue-based rations during the dry period. The results showed that milk from does on conventional concentrate treatment contained the highest percentages of fat (6%), protein (6.33%), total solids (21.85%) and solids-not-fat (15.85%).

2.3. Challenges of dairy goat production.

Inadequate feed was a major limiting factor to small ruminant production in Africa resulting in lower nutrition particularly during the dry season (Ademosun, 1992). This was due to the fact that natural pasture is of low nutritional value during the dry season due to inadequate rainfall. In the arid and semi-arid zones as it was the case in Botswana, rainfall is less than 600 mm per annum (Ademosun, 1992). During the dry season when the quality of available forage is low the animals should have access to supplementary feeds to help minimize production losses in terms of milk in dairy goats. These supplementary feeds can be obtained from agro-industrial by-products such as residues of oil extracted from oil bearing seeds, by-products of grain processing and industrial by-products (Ademosun, 1992). Mpapho (2010) indicated that the challenges that hinder the progress of dairy goat production by smallholder farmers in Botswana include the choice of breed of goats, availability of its breeding stock and inadequate feed.

2.3.1. Lucerne forages as a protein source for goat production

Turner *et al*. (2005) noted that lucerne is the predominant legume for many classes of livestock and it is used to supply crude protein in diets for ruminants. Lucerne is also used extensively in dairy operations where it delivers high protein and calcium needed for high milk production. It is relatively high in calcium and low in phosphorus, therefore, careful ration formulation of the calcium to phosphorus ratio in the total diet must be considered (Nix, 2006). Lucerne produces high yields and high quality forage that is readily consumed by goats and supports superior weight gains (Turner *et al*., 2005). The good forage value of lucerne is not only

that it has higher crude protein content (15-20%) than most forage, but it has lower levels of acid detergent fibre (55-60%) (Wildeus *et al*., 2007).

Sanz *et al*. (1998) in their study determined whether the energy balance of goats or characteristics of the diet consumed were factors that determine milk production. The authors fed goats the same amount of concentrate in two diets with forage in the form of long lucerne hay, and lucerne in a pelleted form. The results indicated that in these diets the amount of milk fat and proteins depended on energy intake. Nitrogen and metabolizable energy utilization for milk production was higher for goats fed pelleted lucerne (Sanz *et al*., 1998). This was because compared to long lucerne hay, pelleted lucerne was consumed in larger quantities and utilized efficiently hence more energy intake was available to the animal performance.

Morand-Fehr *et al*. (2000) assessed the dietary effects on the percentage reversion risks of two fibre sources mainly lucerne hay and dehydrated unground lucerne blocks. The two diets were compared at a low and high roughage/concentrate ratio. The level of dry matter intake (DMI) was not significantly different (2.95, 2.94, 2.88, 2.99 kg DMI/d) for high lucerne diet, low lucerne diet, high dehydrated lucerne block, and low dehydrated lucerne block diets respectively. The type of lucerne had no effect on milk yield. In addition, milk fat percentage was lower in dehydrated lucerne blocks than lucerne hay. Milk protein content increased for dehydrated lucerne block diets.

2.3.2. Lablab forages as a protein source for goat production

Lablab purpureus is a legume which is resistant to drought and will grow well in areas with less than 500 mm of annual rainfall (Aganga and Autlwetse, 1999). According to National Agricultural Research Organisation (NARO) (1997) forage legumes such as lablab are already adapted in the farming systems of

the smallholder dairy farms in Africa. Andrea and Colucci (1999) noted that *Lablab purpureus* had an advantage because of its adaptability, not only due to its resistance to drought; it can grow in a diverse environmental conditions. Being palatable to livestock, lablab is a source of much needed protein and can be utilized in several ways (Andrea and Colucci, 1999) for example as hay, silage and in a total mixed diets with concentrates. It has been observed that lablab has the potential of increasing livestock weight gain and milk production during the dry season (Andrea and Colucci, 1999).

Mupangwa *et al*. (2000) conducted experiments on growing goats offered *Chloris gayana* hay supplemented with *Lablab purpureus* and crushed maize to investigate dry matter intake, digestibility and growth. They found that goats in the supplemented groups had higher total dry matter and nitrogen (N) intakes and higher nitrogen retention and body mass gains than un-supplemented counterparts. The digestibility of dry matter, organic matter and neutral detergent fibre (NDF) were increased by protein supplementation. The production of protein by ruminal microbes and the efficiency of microbial N production were increased by supplementation.

Results from a study with goats reported by Andrea and Colucci (1999) showed that maize stover diets supplemented with lablab resulted in better body weight changes of the does, higher kid birth weights, faster growth rates and more milk as compared to traditional small holder practices in which no supplementation was used. In addition, postpartum anoestrous periods were shorter for supplemented animals than in animals fed typical diets not including lablab. The improved milk yield and a slower decline of yield with time were related to a higher intake of lablab (Andrea and Colucci, 1999). Aganga and Autlwetse (1999) investigated the efficiency of Tswana goats in utilizing buffel grass, sorghum and millet forages supplemented with lablab as a protein source. Their results showed that conversion efficiency of these feeds by goats in all treatments

was the same. Supplementing a basal diet of elephant grass or any other pasture grass with lablab hay showed improved milk production, prevented weight losses and thereafter improved fertility in Uganda smallholder dairy farmers National Agricultural Research Organisation (NARO, 1997).

2.3.3. Milking frequency

Number of daily milking is of great importance in improving milk yield in dairy animals (Salama *et al*., 2003) if feeding, animal welfare, health, and environmental conditions are adequate (Marnet and Komara, 2008). According to Henderson *et al*., (1983), an increase in the frequency of milking leads to an increase in the rate of milk secretion. Maintained milk synthesis depends on frequent milk removal and milk production eventually stops if milk removal ceases. This effect has been explained as a combination of inhibitory effects by the presence of milk in the secretory tissue and an effect of the high intra-mammary pressure (Marnet and Komara, 2008). Less frequent removal of milk inhibits further milk synthesis. Less removal of milk results in reduced blood flow to the udder which can initiate apoptosis (Hogberg, 2011).

Local mammary factors regulate the milk synthesis in each gland (left or right in goats) and they are independent of each other. If milking frequency increases in one gland only, milk yield will increase in that gland but not in the other (Hogberg, 2011). Intervals between milking will affect milk fat composition by as much as 1% between morning and afternoon milking (Marnet and Komara, 2008). Milk fat is lower in the first milk withdrawn during milking, but much higher in the last milk. However, the effect of extended milking intervals varies depending on the breed and genetic merit of animals used (Marnet and Komara, 2008). Stelwagen, (2001) indicated that the milking interval has to be less than 18 hours to avoid adverse effects on milk yield and quality. Compared with twice daily milking, once daily milking has been reported to reduce milk yield by 6 to 35% in dairy goats (Stelwagen, 2001).

2.4. Goat milk production and consumption in Botswana

Smallholder farmers in Botswana, who keep goats, milk them and consume the milk as raw or process it into *madila* (fermented milk) (Moreki *et al*., 2011). The potential demand for goat milk and other dairy products presents opportunities for smallholder dairy goat farmers in Botswana to venture in producing goat milk (Kibuuka, 2011). In addition, a dairy goat in Botswana has shown to give on average 3.4 kg of milk a day under the intensive management system (Mpapho, 2010). Commercial dairy goat farming is not common in Botswana because the current support such as National Master Plan for Arable Agriculture and Dairy Development- (NAMPAADD) for improving dairy industry is focusing on dairy cattle alone.

The government of Botswana has made attempts to do feasibility studies on dairy goat farming by performing on-station research. There was a dairy goat research project in Morale Ranch in Mahalapye under the Department of Agricultural Research which started in 2005. The project was experimenting with pure breeds of British Alpine, Toggenburg and Saanen dairy goats and their crosses. The main focus of the project was to assess the adaptability and milk production of these dairy goats in Botswana. During the experimental period the goats were fed lucerne, brewer's grain and a homemade dairy meal (Animal Production and Range Research Division, 2006). The results obtained indicated that the potential production of all three breeds ranges between 2.0 to 3.5 litres a day (Agrinews, May 2012).

There was also another dairy goat research project at Botswana College of Agriculture which was started in 2009. They were keeping only Saanen dairy goats. One of the key objectives of the research was to breed dairy goats that can effectively produce milk in the semi-arid conditions of Botswana. The preliminary results of the project showed that primiparous goats produced an average of 2.8 kg of milk a day at peak of lactation

(Mpapho, 2010). Regional dairy goat milk production had been recorded to be in the range of 3.3 - 4.0 kg a day at peak of lactation (Mpapho, 2010).

2.5. Government assistance policies on dairy goat production in Botswana

The government is spending money on the dairy sector with the expectation of growing and diversifying the economy (Moreki *et al*., 2011). Lack of specific schemes targeting dairy goat production, dairy import and commodity price had made it difficult for smallholder dairy goat farmers to excel. In 1979 there was a programme Service to Livestock Owners in Communal Areas (SLOCA), which was providing technical assistance to the Botswana Cooperative Union (BCU) to carry out the responsibility of small livestock management and marketing (Mrema and Rannobe, 1994). The government of Botswana established the Financial Assistance Policy (FAP) scheme in 1982, which aimed to create employment and to diversify the economy. The FAP scheme endeavoured to address gender imbalances by giving women more grants (15%) than men. In FAP, one could obtain up to 90% grant for any livestock enterprise, depending on the number of jobs created and the location of the business (Moreki, 2010).

While some FAP projects were successful, the failure rate was relatively high. A major review was undertaken in 1999 and the programme was replaced by the Citizen Entrepreneurship Development Agency (CEDA) from 2001. The Citizen Entrepreneurship Development Agency's mandate is to manage and monitor some of government's financial (loans) and technical assistance schemes to citizens wishing to go into business or to expand existing businesses (Botswana Country Report, 2005). In 2008 the government of Botswana established the Livestock Management and Infrastructure Development (LIMID) scheme to support small stock production. This scheme had increased the interest of farmers to invest in small stock

farming, mainly for meat production. These government schemes improved the lives of smallholder farmers because they managed to rear more goats which they sell and use the money for their daily household needs.

The exclusion of dairy goats by these government schemes had negatively affected local milk production because if goats were included, local milk production could have been increased and importation of milk and milk products would have been reduced. Mpapho (2010) emphasized that problems that needed to be addressed by government policies included accessibility and ownership of land, lack of access to credit facilities to cover cost of establishing and running a small scale dairy goat farm, inadequate infrastructural facilities and incentives that encourage the adoption and utilization of new technologies. Therefore, if the government could re-consider the package of LIMID and include dairy goat farming, local milk production could be increased.

2.6. Opportunities for smallholder dairy goat farmers in Botswana

There are opportunities for small livestock producers to establish profitable livestock enterprises, because of the high increase in the demand for animal products in the African continent. Due to the combined effect of population expansion, the high rate of urban growth and accompanying changes in lifestyles (Nouala *et al*., 2011) the demand for milk will increase. It has been suggested that in Southern Africa as a whole, per-capita milk consumption will increase by 2.2kg/person/year over the period 2000-2030 (Nouala *et al*., 2011). In Botswana, an increase in human population from 2.0 million in the 2011 census indicated an estimated growth of 1.9% between 2001 and 2011, hence demand for local milk and milk products was expected to increase to an estimated volume of 51 million litres per year for 2011 and beyond (Monei, 2011).

The dairy goat industry has great potential for further growth because there is a trend towards self-sufficiency by rural people, especially in developing countries, where goat milk can help to improve the nutrition of millions of people. In developing countries, much of the milk produced by goats is for family consumption. However goat milk can also be further processed into a variety of marketable products such as cheese, *madila*, and yoghurt (Ngambi, 2008). Therefore venturing into dairy goat milk production and its products can produce high quality products for human consumption.

CHAPTER THREE- STUDY ONE

3.0. The current status of smallholder dairy goat production in Central, Kgatleng and Kweneng districts of Botswana: constraints and opportunities.

3.1. Abstract

The situation of dairy goat production in Botswana is not well documented. The aims of the study were to: identify the current status of smallholder dairy goat production in Botswana, identify the production challenges and marketing opportunities of dairy goat farming in Botswana and make recommendations for on-farm improvements to increase milk yield from dairy goats as a way of increasing income and food security to smallholder farmers. Data were collected through a survey using structured questionnaires that were administered face to face to all the identified dairy goat farm owners in Central, Kgatleng and Kweneng districts of Botswana. Data were analysed using the Statistical Package for Social Sciences software. Dairy goat production was dominated by male farmers 75% (9/12), youth and middle aged 67% (8/12) of which the majority held a junior degree qualification 75% (9/12) and had less than five years experience keeping dairy goats. Seven of the respondents (58%) started their dairy goat farms using their monthly income (salary). Fifty-two per cent (52%) of the dairy goat breeds kept by respondents in Botswana were the Saanen, 30% crosses, 12% Toggenburg and British Alpine 6%. Dairy goat production in Botswana is a semi-intensive production system with average milk production estimated to be 3kg milk per goat at peak of lactation since farmers were not regularly measuring milk yield throughout the whole lactation period, but they just rely on the highest milk yields estimates of each goat which basically is at peak of lactation. The challenges faced by the dairy goat industry in Botswana included unavailability of affordable superior breeding stock, insufficient feed, heart-water disease and failure of the exotic breeds to acclimatize effectively to local climatic conditions. The opportunities that were available to dairy goat farmers in Botswana included producing more milk to satisfy the high local milk demand, dairy goat stud breeding and fodder production.

High milk demand in Botswana and the nutritional importance of goat milk is an advantage so that local farmers can regard it as a marketing opportunity to produce more milk from dairy goats.

Key words: Botswana, constraints, current status, dairy goat production, opportunities.

3.2. Introduction

Dairy goats are kept by small-holder farmers in rural areas specifically for milk, meat, skins and manure (Jackson *et al*., 2012). They are prolific and require low inputs for a moderate level of production, reach maturity early, have twining ability and may be more profitable to keep than dairy cattle (Pambu *et al*., 2011). Dairy goats can be easily handled by women and children and produce appropriate quantities of milk for a household consumption (Donkin, 1997). Goat milk is very important in the diets of people, as well as a good, stable source of livelihood for resource poor people in rural areas Foundation For The Carolinas (FFTC, 2008). Goat milk as compared to cow milk has been reported to have a higher medicinal value, differences associated with vitamin B_{12} and high digestibility. It is also a good source of protein which is important for infants, children, patients allergic to cow milk and nursing mothers (Jackson *et al*., 2012).

In Botswana, milk including goat milk, is imported from neighbouring countries at high cost to the economy. This is compounded by the low levels of milk production from indigenous goats (Agrinews, May 2012). Smallholder farmers can take advantage of the high price of goat milk and get motivated to keep dairy goats and increase goat milk production in Botswana (Mpapho, 2010). As the human population in Botswana continues to grow, goat milk will become more important as a source of high quality protein to reduce malnutrition, especially in children (Mpapho, 2010). For many years, researchers at the Department of Agricultural Research (DAR) and Botswana College of Agriculture (BCA) have focused their effort at breeding a dairy goat that can produce milk efficiently in the semi-arid conditions of Botswana (Agrinews, May 2012). Despite there being a considerable amount of published research work on dairy goat production and performance in Botswana, much of this work has been carried out under controlled conditions at research stations, where the results may not reflect the actual situation of small holder dairy goat production systems prevailing in rural areas. This study was carried out to determine the current status and limitations of dairy

goat production in Central, Kgatleng, and Kweneng districts of Botswana and to recommend strategies for improvement.

3.3. Specific Objectives

The specific objectives of this research were to:

3.3.1. Describe the current situation of smallholder dairy goat production in Central, Kgatleng and Kweneng districts of Botswana.

3.3.2. Identify the production challenges and marketing opportunities of dairy goat production in Central, Kgatleng and Kweneng districts of Botswana.

3.3.3. Elicit strategies that can be used to increase dairy goat milk yield as a way of increasing income and food security to smallholder farmers.

3.4. Materials and Methods

3.4.1. Research Design

The study adopted a descriptive survey method. The descriptive analysis approach was considered ideal for this study because it provided quantitative and qualitative descriptions of the target population.

3.4.2. Target population

The study population comprised of the identified farms which were engaged in dairy goat rearing in Central, Kgatleng and Kweneng districts of Botswana. Twelve active dairy goat farmers were identified. These farmers were the only farmers who were keeping dairy goats in Botswana at the time this study commenced. The respondents were selected after considering factors such as accessibility to their farms and willingness of farm owners to provide information from their farms to be used on this research. Dairy officers in each agricultural region were contacted to assist in identification of dairy goat farms available in their regions.

3.4.3. Study Area

The study was conducted in Tonota, Palapye, Mahalapye villages (Central district), Mochudi and Oodi villages (Kgatleng district), Sebele, Molepolole, Kopong, Boatlaname and Ngware villages (Kweneng district) in Botswana from November to December 2013. These villages were the only villages in Botswana which had farmers who were keeping dairy goats at the time of this study (Figure 3.1).

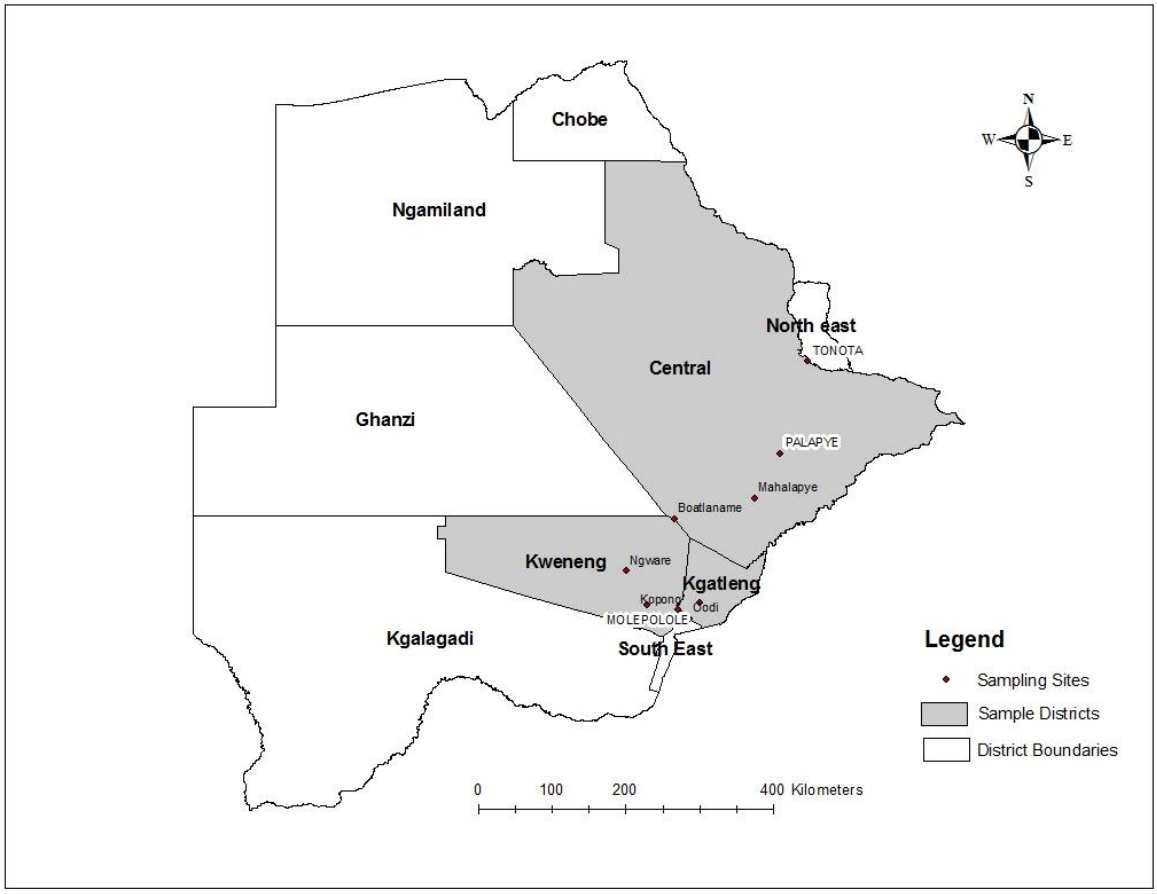

Figure 3.1: The identified dairy goat farms in Central, Kgatleng and Kweneng districts of Botswana which were surveyed

3.4.4 Primary data collection

The study utilized data collected through a survey using structured questionnaires, (see Appendix) administered face-to-face to existing dairy goat farm owners in the study area. The questions were posed in English language but where necessary they were explained to respondents with local Setswana language. Direct observations on animal husbandry and management principles in existing dairy goat farms in Botswana were also conducted. A structured questionnaire was designed to obtain information from respondents on: socio-economic profiles, personal demographic characteristics, breeds of goats kept,

management and production system practised including milking frequency, feeds available for their dairy goats, production constraints and marketing opportunities for dairy goat production. Errors in data collection were minimized by using only one interviewer throughout the course of the data collection.

3.4.5. Secondary data collection

Secondary data that were also used in this research included the dairy annual reports on dairy goat farming at relevant agricultural departments; Agrinews published by Ministry of Agriculture, and trade statistics on dairy goat milk imports from Trade Statistic Unit under the Ministry of Trade and Industry, Botswana.

3.4.6. Statistical Data analysis

Data were analysed using the procedure for Statistical Package for Social Sciences (SPSS) (SPSS, 2008).

3.5: Results and Discussion

3.5.1: Demographic characteristics of respondents

Males were the predominant owners and carers of dairy goats, constituting 75% (9/12) while women contributed the remaining 25% (3/12) of the surveyed respondents (Table 3.1). These results indicated that there was a positive association between gender and keeping of dairy goats in Botswana. Even though the results showed that males were positively associated with dairy goat farming, all the respondents were married, but husbands were more actively involved in milking the goats than their wives and children. The FAO, (2000) indicated that in many societies, cattle and larger animals were usually owned and managed by men, small-stock such as goats and sheep which were kept near the house and more owned and managed by women. The current research results were contrary to the findings of the FAO, (2000). In addition, the FAO (2000) mentioned that livestock gender based patterns were strongly related to the type of production system.

Table 3.1: Demographic parameters of respondents that own or operate dairy goat farms in Central, Kgatleng and Kweneng districts of Botswana

Variable n= 12	Respondents		
Variables	Category	**N**	*%*
Gender	M	9	75
	F	3	25
Marital status	Single	0	0
	Married	12	100
	Divorced	0	0
	Widowed	0	0
Age range	Below 35 years	8	66.7
	36-50 years	4	33.3
	51-60 years	0	0
	Over 60 years	0	0
Education	None	0	0
	Can read and write	0	0
	Primary	0	0
	Secondary	3	25
	Certificate	0	0
	Diploma	0	0
	Degree	9	75
Employment	None	5	41.7
	Fulltime	7	58.5
	Part time	0	0
Ownership	0-5 years	9	75
	More than 5 years	3	25

The active involvement of males in dairy goat production may be attributed to the popular method of milking goats in Botswana which was hand-milking, hence became difficult for women to milk dairy goats and they ended up losing interest in keeping dairy goats. In addition, males may have identified the potential rewards of keeping dairy goats as a business than their wives. Machine milking on dairy goats was common only on government owned dairy goat farms. In contrast to the current research, Muriuki (1992) mentioned that in Kenya women were wholly involved in all aspects of dairy development (39%) compared to men's

contribution of 26%. The current research agreed with the findings of Aganga and Nsoso (2011) who indicated that indigenous goat ownership in Botswana in general was skewed towards male ownership. Seresinhe and Marapana (2011) stated that in Sri Lanka women and children were primarily responsible for the management of the goats while men were responsible for their marketing.

Eight out of the twelve respondents were aged below 35 years while the remaining four respondents were adults of ages ranging between 36-50 years (Table 3.1). The current research results highlighted a significant association between age of the farmer and keeping dairy goats. The results showed that dairy goat farming in Botswana was carried out by young farmers who were relatively more energetic as compared to older people. Nine out of the twelve respondents had a degree certificate and the remaining three respondents had a secondary certificate (Table 3.1). These research findings showed that dairy goat production in Botswana was at that time carried out by knowledgeable farmers, who if given appropriate support, can be able to understand and adopt advanced technologies involved in the dairy industry such as milking machines, silage making, milk and milk products processing, since one of the farmers had intension to build an infrastructure which will be used as a milk processing plant. Aganga and Nsoso (2011) mentioned that for livestock production to benefit smallholder farmers, appropriate support and intervention strategies should focus on empowering process which would enable smallholder farmers to have easy access to animal production training and extension services.

Even though most of the respondents had a degree qualification, they have mentioned that they had less knowledge about the care and management of dairy goats and some said they were not aware that there were short courses that were being offered at Botswana College of Agriculture annually such as dairy goat production and fodder production. This information should be available to all extension offices so that

farmers can easily access it well in time since not all farmers have access to the internet and newspapers in which normally these short courses were advertised. All the respondents were married, seven out of the twelve respondents were employed full time whereas only five of them were unemployed (Table 3.1).

3.5.2. Ownership period of dairy goat farming

The period of dairy goat ownership of respondents is summarised in Table 3.1 (page 24). Out of the twelve respondents, nine of them said they had been keeping dairy goats for a period less than five years, while the remaining three respondents had more than five years experience keeping dairy goats. The current status of dairy goat production in Botswana was significantly associated with inexperienced farmers. Jackson *et al*. (2012) mentioned that in Tanzania dairy goat farming at community level dated back to the 1980s, and it was promoted by development agents in the area. The authors further indicated that the introduction of these dairy goat breeds in rural areas was aimed at upgrading the local breeds in terms of increasing their growth rates, milk yield, and hence improving food security as well as household income. Most of the farmers in Botswana with dairy goats kept from two to ten adult milking goats. Farmers who were currently keeping dairy goats, milked them for household consumption, with only one farmer who was producing more than the household demand and who had the opportunity to supply extra milk to guest houses in the village.

3.5.3 Financial assistance to start up dairy goat farming

The majority of existing dairy goat farm owners (7/12) surveyed in Botswana mentioned that they started their dairy goat farms by utilizing their monthly income (salary). Three out of the twelve respondents were government based farms which depended on annual financial government budget for financing; one out of the twelve respondents surveyed said she utilized bank loans, while another one respondent mentioned that he sold his property to buy dairy goats (Figure 3.2). The government of Botswana was spending money on the dairy sector with the expectation of growing and diversifying the economy (Moreki *et al*., 2011). Lack of specific schemes targeting dairy goat production were said to have made it difficult for dairy goat farmers to grow. The local financial institutions such as Citizen Entrepreneual Development Agency (CEDA) were interested in funding dairy cattle farming because of the economics of scale, and hence this demotivated smallholder dairy goat farmers to submit their proposals for funding.

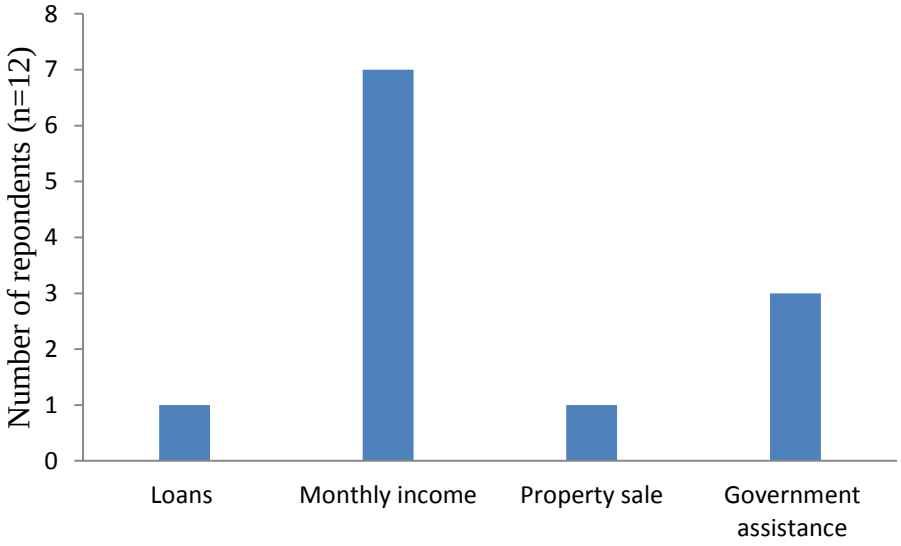

Figure 3.2: Financial Support used to establish dairy goat farms by respondents

One of the farmers mentioned that he once submitted his proposal for dairy goat production in 2009 but the response he got from CEDA was that they could only consider his application if he was aiming to start dairy cattle operation with a minimum number of one hundred breeding stock. Jackson *et al*. (2012) mentioned that on-farm dairy goat farming at community level in Tanzania was promoted by development agents in the area. In Kenya a non-governmental organization (FARM-Africa) implemented a community-based dairy goat multiplication programme using exotic breeds (Saanen, British Alpine, Anglo-Nubian and Toggenburg) to improve the nutrition and incomes of smallholder farmers (Donkin and Boyazoglu, 2001). The aims of the programme were to ensure a sustainable spread of dairy goats in the communities involved using a "pass-on" model contract, and to impart dairy entrepreneurial skills to the farmers. The "pass-on" contract model required a beneficiary of a doe to pay in-kind by giving out the first two female offspring free to the next listed beneficiary who will in turn do the same (Ogola *et al*., 2010). The adoption of this practice in Botswana would help empower smallholder farmers with a hands-on knowledge about keeping and management of dairy goats. Moreover, farmers would recognize the importance of dairy goats to their daily welfare and household income because they would be using the goat milk for household consumption and sell surplus.

3.5.4. Other sources of income

Apart from selling live dairy goats and goat milk, three out of the twelve surveyed respondents mentioned that they also depended on arable farming, three of the twelve respondents said they depended on selling indigenous goats and sheep, three of the twelve respondents depended on selling beef cattle, one of the respondents depend on part time jobs while another one respondent depended on horticulture for other sources of income. Three of the twelve surveyed respondents were government based dairy goat farms as they depended on annual government funds as their source of income to run their daily farm activities (Figure 3.3). The research findings indicated that there was a significant association between the source of income

and dairy goat rearing in Botswana by smallholder farmers. The results agreed with those of Eik *et al*., (2008) who found that on average dairy goat farm owners in Mgeta, Tanzania relied on arable farming as their main source of income for almost all families. According to Donkin and Boyazoglu (2001) lack of funds have limited the outreach and extension activities for promoting keeping of dairy goats by smallholder farmers in developing countries. Selling of male dairy goats for breeding purposes was popular among all the respondents in the study area. The majority of the respondents mentioned that they preferred keeping male goats separated from the entire flock until they were mature so that they can sell them at a high price. They normally left them behind in kraals to feed them when female goats went out for grazing on the fields.

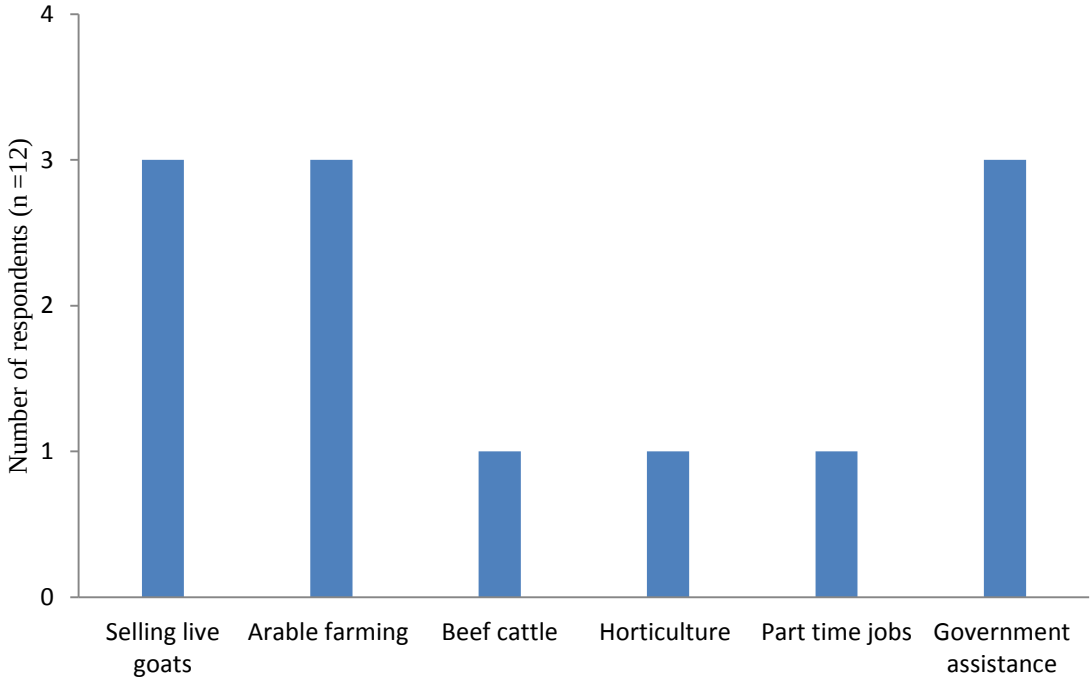

Figure 3.3: Other sources of income of respondents

3.5.5. Dairy goats in Botswana

3.5.5.1. Dairy goat breeds in Botswana

At the time this research was conducted from the twelve respondents, there were fifty-two (52) Saanen goats, thirty (30) crosses, twelve (12) Toggenburg and six (6) British Alpine goats (Figure, 3.4). Majority of these goats were from government owned dairy goat farms. Saanen goats were the dominant breed since farmers preferred the breed because of its high milk production potential. According to the Ministry of Agriculture annual report (MOA) (2014) in Botswana, there were 2.4 million goats. These statistics does not include dairy goats because they were very few at that time. Lack of statistics of dairy goats is due to the fact that a management system of small-scale household dairy production is not well established in Botswana. Indigenous goats in Botswana were mainly kept for meat with some farmers milking them only for household consumption (Moreki *et al*., 2011).

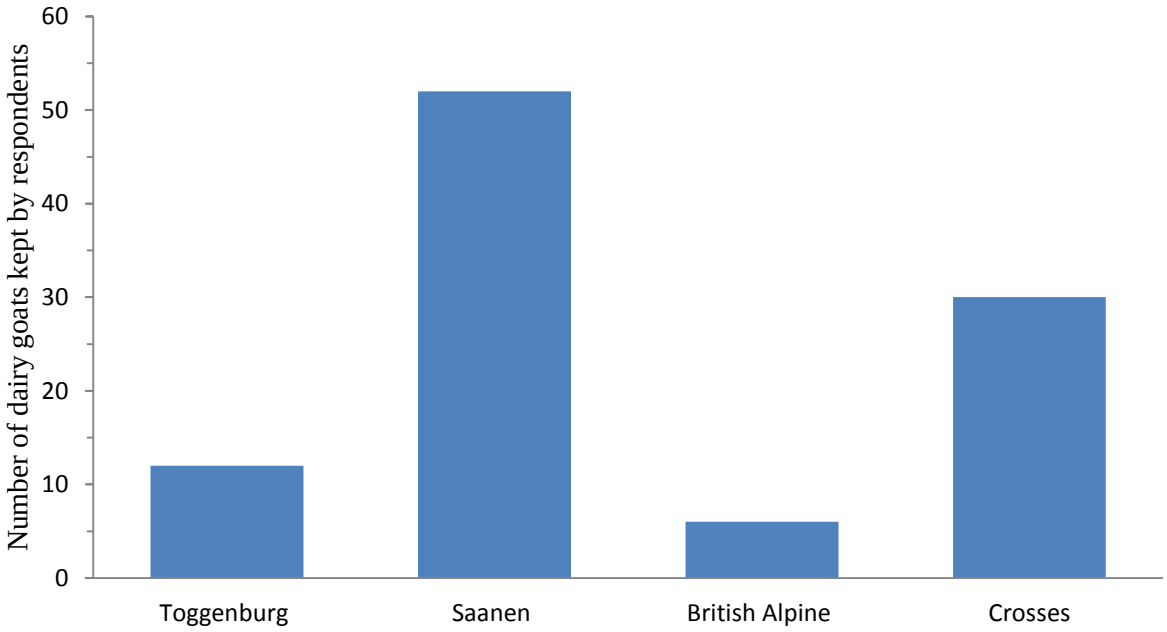

Figure 3.4: Breeds of dairy goats kept by respondents

3.5.5.2. Management of dairy goats in Botswana

3.5.5.2.1. Provision of shelter

Dairy goat farmers in Botswana were providing shelter for the dairy goats. Five respondents constructed their goat kraals with mesh wire and gum poles with corrugated iron roofs, four respondents used metal poles with mesh wire and corrugated iron roofs, while only three respondents constructed their dairy goat kraals with indegenous tree poles and mesh wire without any roofing provided to animals (Figure 3.5). The shelter generally provided to dairy goats in Botswana were just simple structures which basically protected the animals from heat of the sun but not from rain. Since most of them did not remove kraal manure from their goat kraals, they mentioned that their animals were more susceptible to foot rot during the rainy season. Dairy goat farms which were owned and operated by government institutions were the only farms where kraals were constructed with metal poles and mesh wire, and the type of shelter was able to protect the animals from the heat of the sun and rain (Figure 3.5). Kibuuka (2011) mentioned that the setting up of a dairy goat enterprise entails lower capital investment concurrent with lower risks. In addition, dairy goats can be reared in urban and peri-urban areas because the faecal consistence (pellets) is easier to handle and dispose than the bulky cow dung.

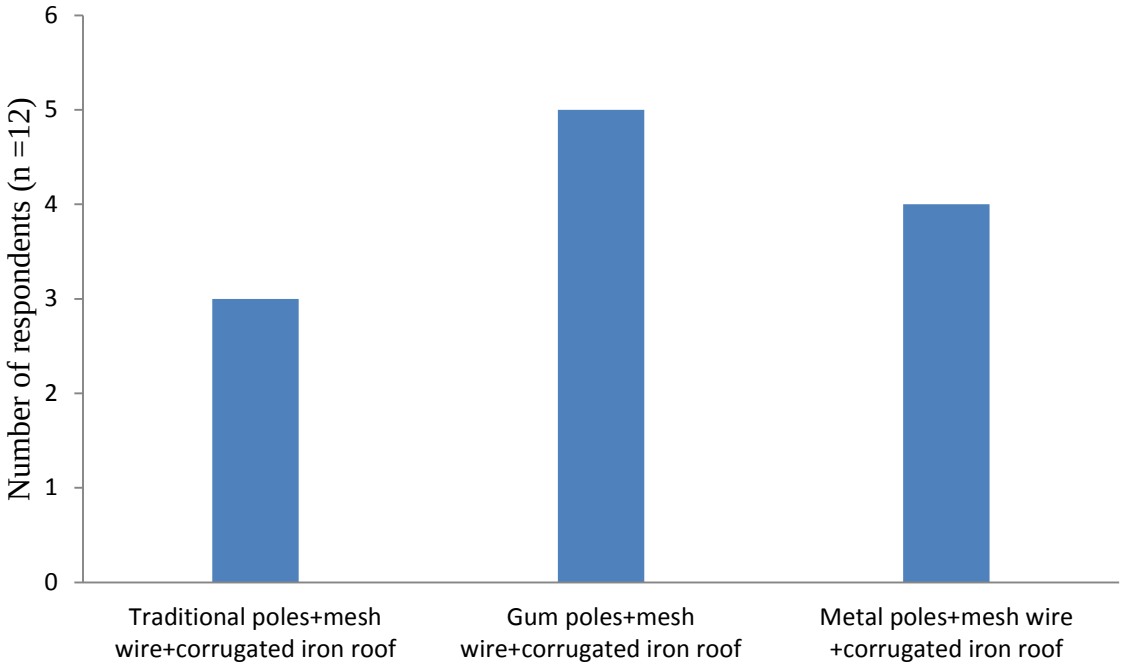

Figure 3.5: Type of shelter provided to dairy goats by respondents

3.5.5.2.2. Feeding dairy goats in Botswana

The majority of these smallholder dairy goat farmers in Botswana were practising semi-intensive production system. Their dairy goats were feeding on natural veld comprising of Tree Savanna to SemiArid Shrub Savanna. The shrubs consisted of Acacia e.g. *A. mellifera, A. giraffae, A. haematoxylon* in the south and towards north *Boscia albitrunca, Dichrostachys cineria, Terminalia sericea* also occur. During the day dairy goats are allowed to roam around the fields or farms browsing the shrubs and they were brought back to their kraals in the afternoon to be fed with lucerne or lablab hay, available supplements (such as, maize and sorhum bran, salt blocks, and dicalcium phosphate) especially during the dry season, and water was provided *ad libutum*. Eight of the twelve interviewed farm owners said that their animals depended on browsing the Tree Savanna and SemiArid Shrub Savanna for maintanance but they also bought lucerne and lablab hays and locally available commercial concentrates for dairy goats during the dry season to feed their animals. Two of the farm owners interviwed mentioned that their animals depended on browsing the Tree Savanna and

SemiArid Shrub Savanna only, while only one farmer said that he was feeding his dairy goats with lucerne hay and local commercial concentrates for dairy goats (Figure 3.6). The farm on which dairy goats were fed with only lucerne hay and locally available commercial concentrates was a goverment owned dairy goat farm and their animals were intesively kept. The goat as compared to a cow eats little, occupies a small area and can produce enough milk for the average family consumption. Maintaining a cow at home often cannot be afforded by smallholder farmers, hence, the growing popularity of goat to be kept by less-resourced farmers(Aziz, 2010). This has led to increased interest in using dairy goat production in poverty reduction by government and non-governmental organisations in Tanzania (Jackson *et al*., 2012).

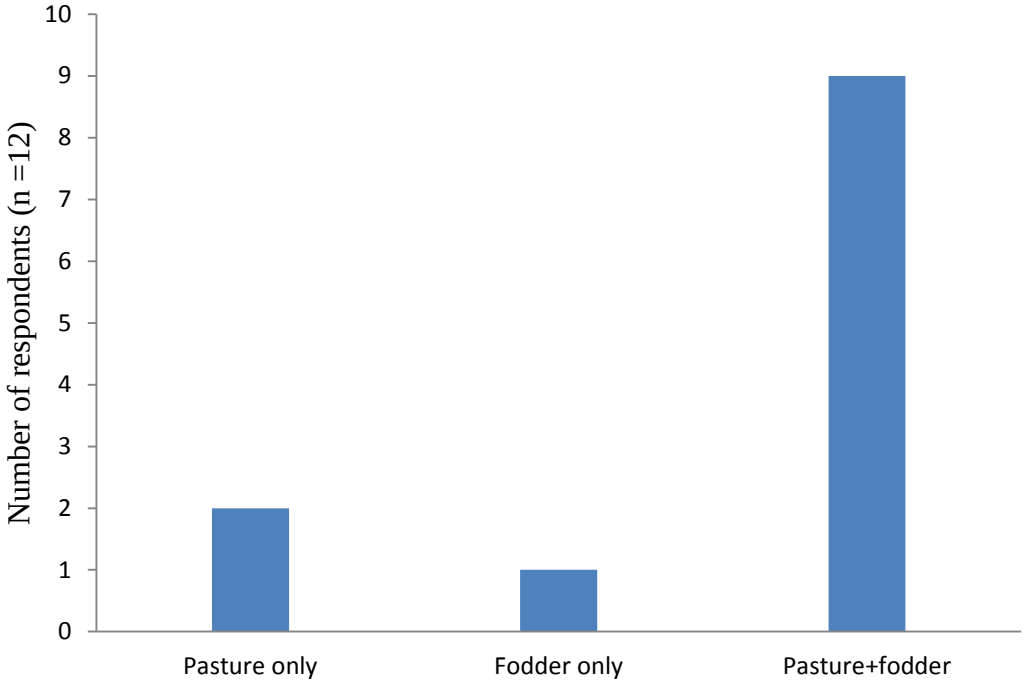

Figure 3.6: Kinds of feeds provided to dairy goats by respondents

The type of forages that local farmers bought to feed their dairy goats included lucerne and lablab hay. During the dry season when the quality of available forage was low the animals were given supplementary feeding to help minimize production losses in terms of milk production in case of lactating animals. Farmers who

were using lablab based rations said that they depended on this type of supplementation because it was cheaper to produce since they were able to produce lablab during the rainy season and reduced their expenses on buying feeds. One of the respondents indicated that he was not giving any type of supplements to his dairy goats, they were depending on the natural vegetation (Tree Savanna and SemiArid Shrub Savanna) for maintanance; four of the respondents mentioned that they were supplementing their animals with either lucerne or lablab based total mixed rations, Three of the twelve respodents depended on locally available commercial concentrates for dairy goats to supplement their animals during the dry season. (Figure 3.7). Ademosun (1992) indicated that supplementary feeds can be obtained from agro-industrial by-products such as residues after oil has been extracted from oil bearing seeds, by-products of grain processing and other industrial by-products. Feed shortages contribute negatively to small ruminant production in Africa resulting in lower nutrition particularly during the dry season (Ademosun, 1992).

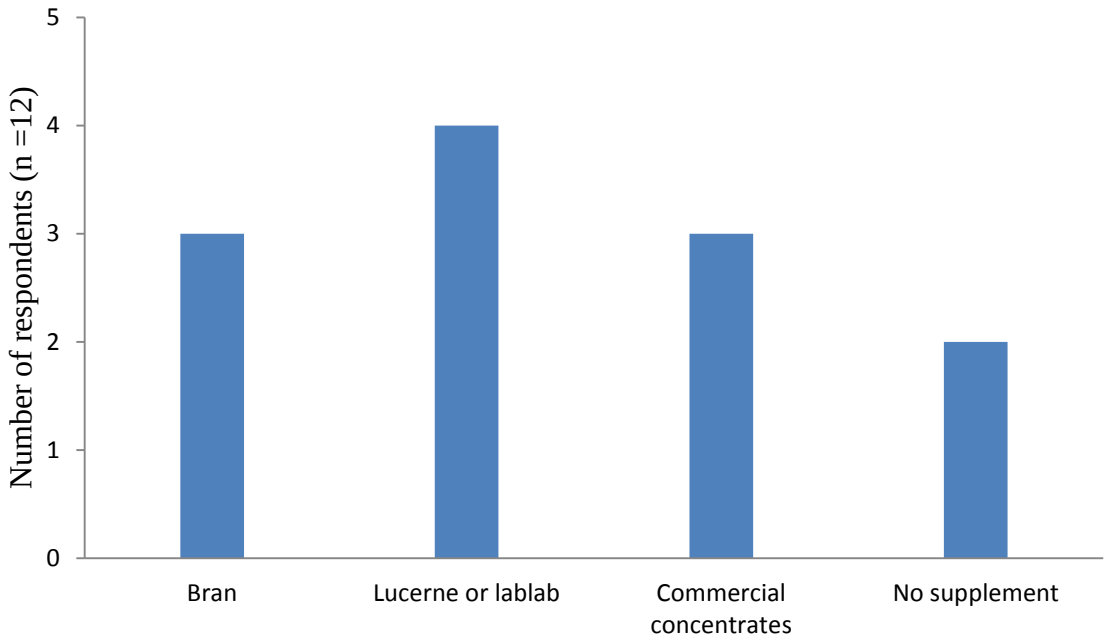

Figure 3.7: Type of supplement provided to dairy goats by respondents

3.5.5.2.3. Milking frequency

Six out of the twelve respondents that were interviewed during the study period mentioned that they milked their dairy goats two times a day (morning and evening), five respondents reported that they milked their dairy goats once a day (Figure 3.8). Farmers who were milking their dairy goats once a day reported that they practised a partial suckling system, where by they separated the kids at night and then milk the goats in the morning, and allowed the kids to suckle from their dams during the afternoon when they returned from grazing areas. However, farmers who milked their dairy goats two times a day mentioned that they milked once per day (morning) during the pre-weaning period and they milked twice (morning and evening) during post-weaning period. The number of daily milkings was of great importance in determining milk yield in dairy animals (Salama *et al*., 2003) if feeding, animal welfare, health, and environmental conditions were adequate (Marnet and Komara, 2008). According to Henderson *et al*., (1983), an increase in the frequency

of milking leads to an increase in the rate of milk secretion. Maintained milk synthesis depended on frequent milk removal and milk production eventually stops if milk removal ceases.

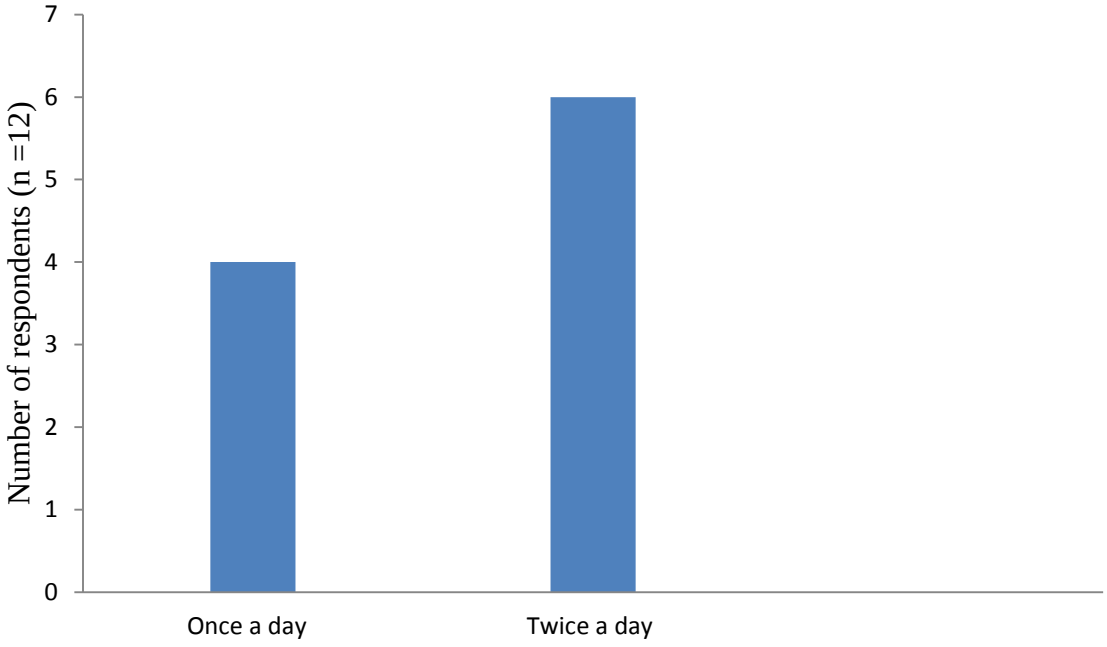

Figure 3.8: Frequency of milking dairy goats by respondents

3.5.5.2.4. Dairy goat milk production in Botswana

Four of the twelve surveyed respondents mentioned that the average milk yield produced by each goat at peak of lactation ranged between 1.0-3.0 kg/d. Milk yield was estimated at peak of lactation because farmers were not regularly measuring milk yield throughout the whole lactation, rather they depended on the highest milk production estimates of each goat which probably is at peak. Three of these respondents were government owned dairy goat farms and their animals were intensively kept during lactation period. Four of the interviewed respondents indicated that they never bothered to take note of how much on average their goats are producing (Figure 3.9). Taking into consideration the fact that in most of the farms these animals depended on natural pasture for their maintenance, their ability to produce on average three kilograms of

milk per day at peak of lactation period is an opportunity to take advantage of and start producing goat milk in Botswana to help reduce the local milk imports. Donkin (1997) also indicated that in South Africa, Saanen and crossbred goats have shown to produce more milk and sustained milk production for a 9 or 10 month lactation as compared to indigenous goats.

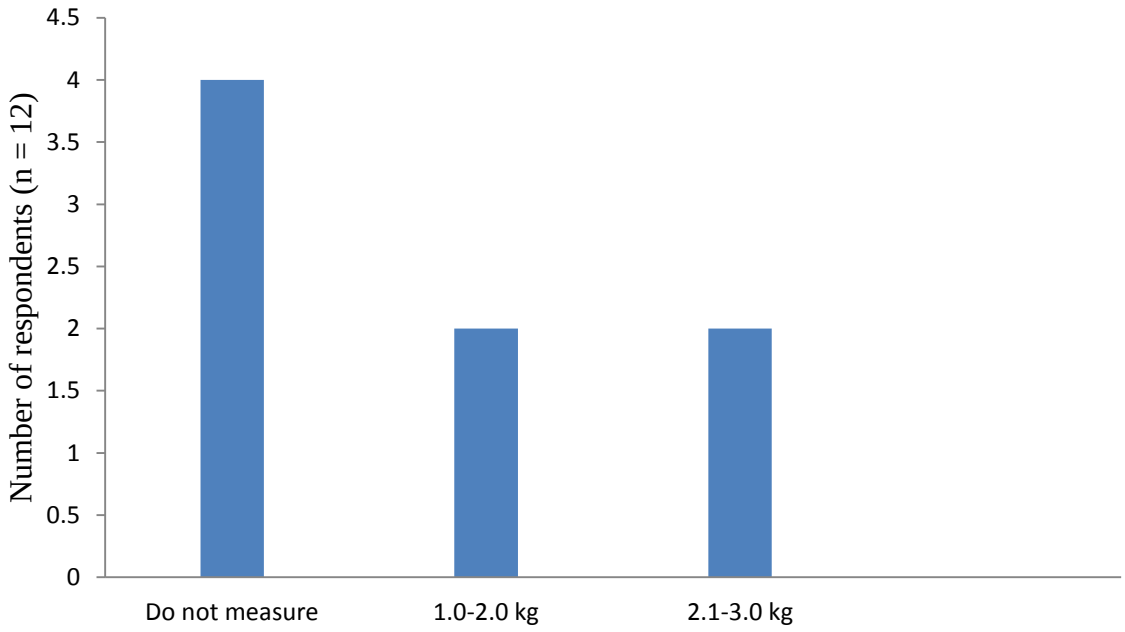

Figure 3.9: Estimated average milk yield per goat/at peak (kg) of dairy goats owned by respondents

According to Jackson *et al*. (2012) dairy goats in Tanzania have gained popularity as a source of milk for rural household consumption and income. Indigenous goats have shown very high levels of milk fat and protein, than Saanen and crossbred goats but produced very small amounts of milk for a short period of time (Donkin, 1997). Milk production from dairy goats requires less capital investment, such as land and labour as compared to cattle (Norris *et al*., 2011). The results of this current research showed a higher milk production from the dairy goats that were kept on farm (3.0 kg/day) as compared to on-station production (2.75 kg/day). These results agree with that of Jackson *et al*. (2012) who mentioned that in Tanzania on-farm dairy goat keeping at community level did well as compared to station-based production.

3.5.7. Challenges of dairy goat production in Botswana

Six of the twelve interviewed respondents mentioned that availability of breeding stock was the major problem to dairy goat production and improvement in Botswana; Three respondents indicated that lack of financial assistance contributed to their low production; while one of the respondents attributed the low dairy goat performance to lack of acclimatised exotic breeds, one respondent to insufficient feed due to drought, one respondent to inadequate knowledge about the care and management of dairy goats and one respondent to loss of their animals due to diseases such as heart-water (Figure 3.10). Almost all the respondents complained about losing animals because they did not get help from animal health extension service at the right time. Seasonal breeding and the resulting annual fluctuations in goat milk supply had made development of new markets difficult and had reduced the importance of considering high milk yield production as a breeding goal for dairy goat farmers (Aziz, 2010).

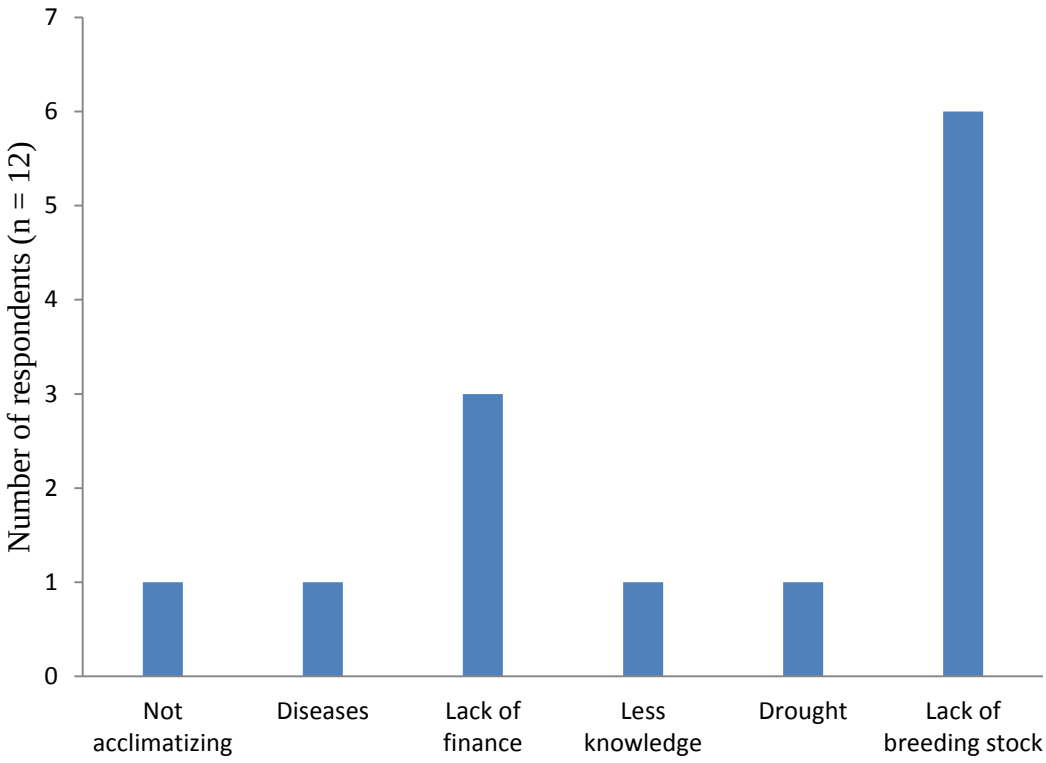

Figure 3.10: Challenges of dairy goat production as perceived by respondents

3.5.7.1. Opportunities for smallholder dairy goat farmers in Botswana

The dairy goat industry in Botswana had great potential for further growth. Six of the twelve interviewed dairy goat farmers indicated that high demand for goat milk in the country was an opportunity for farmers to invest and produce goat milk and milk products. Three of the respondents mentioned that starting a dairy goat stud breeding operation in Botswana was one of the possible opportunities that farmers could start to supply local people with breeding animals, whereas only two the respondents mentioned that producing fodder for dairy goat feed in the country could be a lucrative business (Figure 3.11). Due to the combined effect of population expansion, the high rate of urban growth and accompanying changes in lifestyles the demand for milk will increase (Nouala *et al*., 2011). The dairy goat industry has grown partly because of a trend towards self-sufficiency by smallholder farmers, where goat milk can help to improve the nutrition of

millions of people (Aziz, 2012). Ngambi (2008) mentioned that goat milk can be processed into marketable products such as cheese, *madila*, and yoghurt. However, in Botswana marketing of goat milk and its products is not well established. So far, there had been no local goat milk marketing efforts attempted, rather it was imported from neighbouring countries and sold at high prices in big supermarkets at around P16/kg (approximately US$2.30/kg at the time of the study).

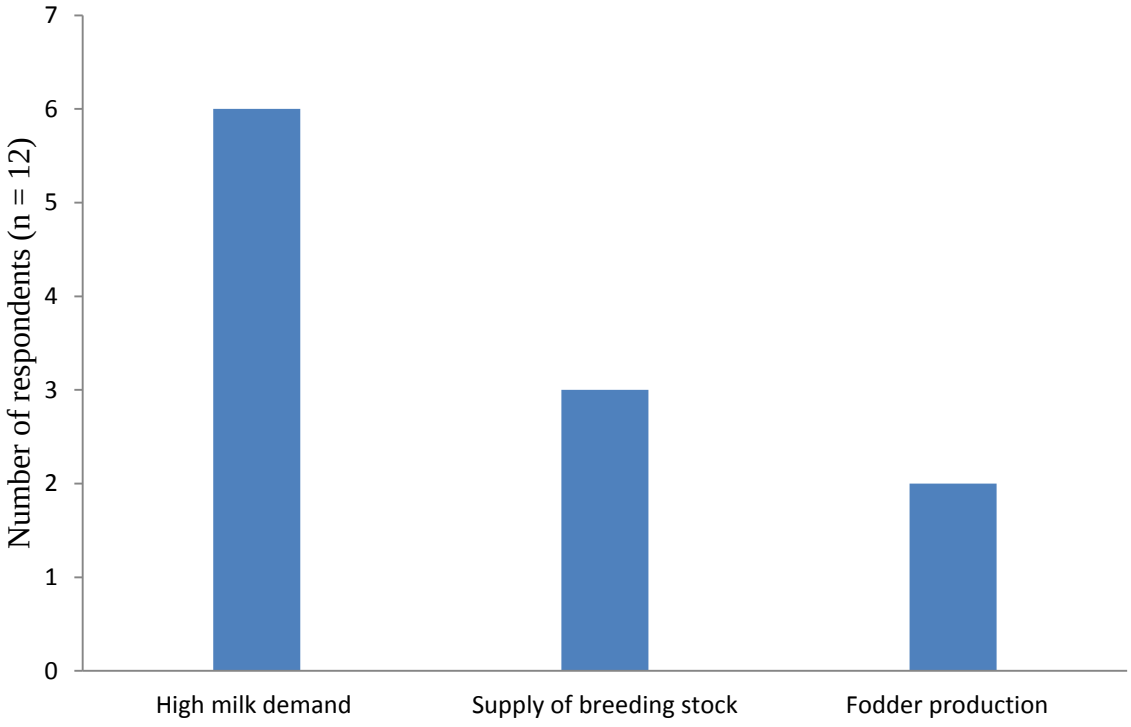

Figure 3.11: Opportunities of dairy goat production as perceived by respondents

3.6. Conclusions

Dairy goat production in Botswana at the time of this study was dominated by middle aged male farmers with less than five years experience. There were only twelve farms keeping dairy goats. Most dairy goat farmers were employed full time and most of them had utilized their monthly income to start up dairy goat farming. Farmers were keeping less than ten goats per farm which were largely exotic and managed in a semi-intensive system with an estimated average milk production of 3.0 kg at peak of lactation period. The highest milk production estimate of each goat was used which probably was at peak of lactation since farmers were not regularly measuring milk yield throughout the whole lactation period. Even though only 12 farmers were identified as the only farmers who were actively involved in dairy goat production in the entire country during the period of this research, majority were keeping dairy goats for household milk consumption with a few selling the surplus milk.

The unavailability of affordable breeding stock, lack of specific financial assistance to dairy goat farming and failure of the exotic breeds to acclimatise effectively to the local environment and diseases such as heart-water disease were perceived to be the main constraints which demotivated farmers from their interest in dairy goat production. Frequent droughts which led to the unavailability of good quality feeds and inadequate knowledge of farmers about the management of dairy goats were among the challenges local farmers were facing when venturing into dairy goat production. Fodder production and stud breeding of dairy goats in Botswana were opportunities that local dairy goat farmers can invest in. High milk demand in Botswana and the nutritional importance of goat milk was an advantage that local farmers can regard as a marketing opportunity to produce more milk from dairy goats.

3.7. Recommendations

Local farmers should be encouraged to take up dairy goat farming as a business and refrain from visiting their farms only during the week-ends and public holidays. Future research on management and production of dairy goats should involve collaboration with dairy goat farmers, on-farm rather than on-station. This could give farmers hands-on experience and be able to understand the challenges that are encountered during management of dairy goats. Improved breeding, feeding affordable quality feeds and right management principles of dairy goats should be encouraged to local farmers in order to increase the performance of dairy goats in Botswana.

CHAPTER FOUR -STUDY TWO

4.0. The Effect of feeding total mixed rations using either *Medicago sativa L* or *Lablab purpureus* hay and milking frequency on milk yield and composition of mid-lactating Saanen dairy goats managed under an intensive system in Botswana

4.0. Abstract

In Botswana, feed shortages in terms of quantity and quality negatively affect dairy goat production. The study was conducted to determine the effects of feeding lucerne and lablab total mixed rations (TMR) and milking frequency (two times and three times daily milking) on dry matter intake, milk production and milk composition of mid-lactating Saanen dairy goats managed under an intensive system in Botswana. Twenty eight lactating Saanen goats (14 primiparous and 14 multiparous) were allocated to a 2 x 2 factorial arrangement in Randomized Complete Block Design. Goats were individually housed and fed in kraals under common roof. The study was conducted at Botswana College of Agriculture small-stock farm for a period of seventy days. Goats were allowed to acclimatize to the feed for a period of seven days before the start of the experimental trial. Milk yield, Dry matter intake, Body weight gain and Milk composition were analysed by General Linear Model procedures in Statistical Analysis System. Milk yield and dry matter intake was recorded daily while Body weight gain and milk composition was recorded weekly. Milk yield, dry matter intake, lactose yield, energy corrected milk, energy efficiency, and fat efficiency were significantly influenced by feeding lucerne or lablab based rations. Goats fed the lucerne based ration produced significantly higher average milk yield (2.51±0.067 vs 2.21±0.067 kg/d; P=0.0016), had a higher DMI (2.49±0.067 vs 2.19±0.067 kg/d; P=0.0016) and 4% FCM (2.15±0.049 vs 1.84±0.049 kg/d; P<0.0001) than goats that were fed the lablab ration respectively. Milk yield (2.65±0.068 vs 2.10±0.068 kg/d; P<0.0001), DMI (2.60±0.067 vs 2.07±0.067 kg/d; P<0.0001), 4% FCM (2.18±0.050 vs 1.81±0.050 kg/d; P<0.0001) were significantly

higher in goats that were milked twice a day than goats that were milked three times a day, respectively. Milk yield (2.75±0.108 kg/d: P<0.0001), DMI (2.72±0.107 kg/d: P<0.0001), and 4% FCM (2.27±0.089 kg/d; P<0.0001) were significantly higher for goats that were fed lablab based ration and milked twice a day while goats that were fed lablab ration and milked three times a day produced significantly lower milk yield (1.80±0.108 kg/d; P<0.0001), DMI (1.78±0.107 kg/d; P<0.0001), and 4% FCM (1.50±0.089 kg/d; P<0001). Feeding lucerne and lablab based rations and milking twice and thrice a day significantly influenced dry matter intake, milk yield and milk composition of Saanen goats. Body weight gain was not significantly influenced by feeding either lucerne or lablab total mixed rations. Local dairy goat farmers should be encouraged to feed their animals with lablab based rations since they can produce more milk at a lower cost. Farmers can adopt milking their dairy goats two times a day because it has been shown to produce more milk than three times daily milking although this result was different from those reported in other researches.

Key words: Feeding, intensive system, milking frequency, milk yield and composition, Saanen goats.

4.2. Introduction

Forage unavailability in terms of quantity and quality hampers dairy production in Botswana (APRRD, 2006). Local dairy farmers usually use fodder crops such as Lucerne (*Medicago sativa L),* Lablab (*Lablab purpureus)* and Napier grass (*Pennisetum purpureum)* to feed dairy goats (Agrinews, May 2012). In Botswana shortage of suitable land and unpredictable weather conditions are the major constraints to dairy cattle production and limit the possibility of forage production for dairy animals (APRRD, 2011). Dairy goats may be used for milk production because as compared to dairy cattle, dairy goats require low production costs than dairy cattle (Monzon-Gil *et al*., 2010).

Goat feeding behaviour depends on the availability of concentrates and forages (Morand-Fehr and Sauvant, 2003). As such feeding goats will involve combining various feedstuffs into an acceptable and palatable ration to meet their nutrient requirements (Brown-Crowder, 2003). Nix (2006) indicated that feeding dairy cattle with lucerne rations can deliver high protein and calcium needed for milk production. Feeding lablab rations also had been observed by Andrea and Colucci (1999) to have the potential of increasing livestock weight gain and dairy cattle milk production during the dry season.

Nowadays, dairymen have adopted the increasing milking frequency as an effective management tool to improve milk production in dairy cows (Shields *et al*., 2011). Wall and McFadden (2012) indicated that regular removal of milk from the milk secreting cells (mammary gland) of dairy cattle is critical for increasing milk production. The increase in milk yield during different milking frequencies in West African Dwarf goats has been noted by Williams *et al*. (2012) to be achieved with little loss of body weight and the extra nutrient requirement being met by an increased feed intake.

Goat milk has been shown to contain approximately 87% water and 13% dry matter, of which the proportion of fat and protein is the most important aspect of the milk chemical composition (Piliena and Jonkus, 2012). In addition to better digestibility of fat and the lower allergenicity of protein fraction, goat milk contains high quality proteins and high content of minerals and vitamins (Brito *et al*., 2011). Although farmers are becoming more interested in rearing dairy goats, studies conducted to evaluate the use of leguminous forage based rations and milking frequency on milk production of dairy goats are limited (Mpapho, 2010). The aim of this research was to investigate the effects of feeding lucerne or lablab hay total mixed rations and different milking frequency on milk yield and milk composition of mid-lactating Saanen dairy goats kept intensively.

4.3. Specific objectives

The specific objectives of this experiment were to:

4.3.1. Determine dry matter intake, milk production and milk composition of mid-lactating Saanen dairy goats fed lucerne and lablab total mixed rations.

4.3.2. Determine the effects of milking mid-lactating Saanen dairy goats two times and three times a day on dry matter intake, milk yield and milk composition.

4.3.3. Compare the production cost of feeding lucerne and lablab rations to Saanen dairy goats milked twice and three times a day at mid-lactation stage.

4.4. Hypotheses

- **H_{O1}:** Feeding either Lucerne or Lablab ration has no effect on milk yield and milk composition of mid-lactating Saanen dairy goats.
- **H_{A1}:** Feeding either Lucerne or Lablab ration has a significant difference on milk yield and milk composition of mid-lactating Saanen dairy goats.

- **H_{O2}:** Milking two times and three times a day has no effect on milk yield and milk composition of mid-lactating Saanen dairy goats.

- **H_{A2}:** Milking two times and three times a day has a significant difference on milk yield and milk composition of mid-lactating Saanen dairy goats.

4.5. Materials and Methods

4.5.1. Location of study area

The study was conducted at the Botswana College of Agriculture small-stock experimental farm near Estate Management Unit, Sebele content farm, under the approval of the Research and Publication Committee. Sebele is located 10 km from Gaborone in South-East district of Botswana. The site is situated at 25.94^{o} S, 24.58^{o} E at an altitude of 991 meters, with mean annual rainfall of 350 millimetres and average monthly maximum temperatures of 30^{o}C and minimum of 15^{o}C (Animal Production Range and Research Division, 2011).

4.5.2. Feed preparation

Medicago sativa (lucerne) hay was purchased from a local commercial producer and *Lablab purpureus* (lablab) hay was purchased from an individual farmer in Pitsane, (Southern Botswana). These forages were chosen for this experiment because they were the only readily available leguminous forages used by both dairy cattle and goat farmers in Botswana. In addition, their high protein content and acid detergent fibre make them suitable for goats feeding since they will be digested efficiently by dairy goats to produce enough milk. Tswana Cowpeas was one of the relevant protein sources that dairy goat farmers in Botswana could use, but its affordability was a challenge. Despite the fact that lucerne as compared to lablab requires irrigation, local livestock feed companies import the lucerne bales in large quantities from neighbouring countries and make it available to local dairy farmers. This only become a challenge when there is an outbreak of livestock diseases in countries where these feeds are imported which results in feed import ban during that period. The hays were purchased in October 2012 and stored in air-ventilated feed-shed until they were chaffed with a hammer mill [Model Drostsky hammer mill by Aktief (Pty) Ltd, South Africa] and stored in open bags. The size of the hammer mill sieve used was 1.5 cm because it was the only used for Smallstock

feeds in the college. During the course of the experiment the hays were sampled every two weeks and ground with hammer mill (Model MF 10, IKA®, Werke, Germany) using a 1mm sieve and then stored at room temperature in tightly closed 200mL plastic jars for analysed for their chemical composition. After chemical composition analysis these feeds were used to re-formulate with commercial concentrate, and sunflower cake to make two total mixed rations.

4.5.2.1. Feed analysis

The dry matter (DM) content of the feed ingredients was determined by oven-drying at 102 ± 2 ^{o}C for 24 hours. Crude Protein (CP) was analysed using the Kjeldahl method according to AOAC (1996). Ether extract was measured after acid hydrolysis to recover saponified fat by extraction with petroleum ether (AOAC, 1995). Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) components were determined by the methods of Van Soest *et al*. (1991) and was determined by a filter bag technique using a Fibre Analyser (model ANKOM^{2000} technology Corp. Fairport, New York, United States of America). Net energy lactation (NEL) was calculated according to INRA, 1989, USA. Calcium (Ca) was measured using Inductively Coupled Plasma/Optical Emission Spectroscopy (Model Optima^{TM} 2100 DV, Perkin Elmer® precisely, Germany), and Phosphorus (P) was determined using UV-Vis Spectrophotometer (Model UV-1601, Shimadzu Corporation, Japan. For the commercial concentrate the manufactures specification was used for its chemical composition (Table 4.1).

Table 4.1: Least squares means and standard errors for chemical composition (%) of feeds used to formulate rations for mid-lactating Saanen dairy goats raised under intensive management system

	Feeds			
Parameter	Lucerne ± SEM	Lablab ± SEM	Concentrate ± SEM	Sunflower cake± SEM
DM (%)	98.38±0.09	98.69±0.09	99.00±0.09	99.09±0.09
ADF (%)	33.71±0.14	31.86±0.14	13.67±0.14	33.29±0.14
NDF (%)	51.30±0.50	40.33±0.50	29.07±0.50	36.41±0.50
EE (%)	1.80±0.13	1.53±0.13	2.64±0.13	2.78±0.13
CP (%)	16.09±0.15	13.57±0.15	14.92±0.15	36.22±0.15
Ca g/d	1.49±0.21	1.16±0.21	0.90±0.21	3.62±0.21
P g/d	0.28±0.19	0.33±0.19	0.40±0.19	3.58±0.19

DM = dry matter, ADF = acid detergent fibre, NDF = neutral detergent fibre, EE = ether extract, CP = crude protein, Ca = calcium, P = phosphorus, SEM= standard error of means; Means within the same row have the same SEM.

4.5.2.2: Formulation and analysis of experimental rations

Lucerne and lablab total mixed rations were formulated for mid-lactating dairy goats with twin kids and producing 1.47 to 2.3kg/d of milk, to supply energy for maintenance and lactation energy requirements of 1.91kcal/kg, 17% Crude protein (CP), 10.3g/d calcium (Ca) and 6.7g/d phosphorus (P). Formulation of these rations was done using Pearson Square formulation technique. Since the protein content of lablab hay was about 4% lower than that of lucerne hay, sunflower cake was added to the lablab ration to increase its crude protein content (Tables 4.2 and 4.3). The rations were formulated according to National Research Council standards (NRC, 2007).

Table 4.2: Proportions of the feed ingredients as per each formulated ration for mid-lactating dairy goats raised under intensive management system.

Feed ingredient (%) in the diet	Lucerne ration	Lablab ration
Commercial concentrate (%)	54.35	54.51
Lucerne hay (%)	45.65	0
Lablab hay (%)	0	38.82
Sunflower cake (%)	0	6.67

Table 4.3: Least squares means and standard errors of the proximate nutrient compositions (%) of the treatment diets that were used to feed Mid-lactating Saanen dairy goats raised under intensive management system

Parameter	DM %	ADF %	NDF %	EE %	CP %	NEL kcal/d	Ca g/d	P g/d
Lucerne ration	98.64[a]	27.02[a]	38.96[a]	2.17[a]	16.99[a]	1.91[a]	7.60[a]	6.08[a]
Lablab ration	98.75[a]	27.07[a]	38.96[a]	2.36[b]	16.98[a]	1.90[a]	7.96[a]	6.39[a]
SEM	0.13	0.09	0.12	0.05	0.05	0.05	0.22	0.19
LSD	0.41	0.28	0.37	0.15	0.16	0.02	0.70	0.60

DM = dry matter, ADF = acid detergent fibre, NDF = neutral detergent fibre, EE = ether extract, CP = crude protein, NEL kcal/d= estimate energy for lactation in kilocalories per day, Ca g/d = calcium in grams per day, P g/d = phosphorus in grams per day, SEM= standard error of means; Means within the same column have the same SEM; [ab] means with the same superscript within a column are not significantly different P>0.05; LSD = least significant difference.

4.5.3. Animals, diets and management

Before the start of this experiment, the Saanen goats were group fed with lucerne hay and local commercial concentrate feed separately (not as a total mixed ration). They were fed once a day at 08:00 hrs in the morning. The goats were bred naturally from April to May each year and started kidding in September. Fifteen of them gave birth to twins, eleven give birth to singles and only two gave birth to triplets. They were previously milked with a machine two times a day at 08:00 hrs in the morning and 15:30 hrs in the afternoon. The previous preliminary milk production results for the whole lactation period (September-June) indicated that on average they were producing 3.4 kg of milk a day. At the time when this experiment started there were no data available on production for early lactation period because of the insufficient budget hence the project was terminated and the dairy goats were handed over to the college farm management. Goats used on this experimental trial were aged between one year old (primiparous) and two to four years old (multiparous).

All goats were not pregnant throughout the experimental period. The goats were intentionally not bred during the experimental period because it was realized that breeding period may disturb data collection and affect the results since the goats were naturally bred with a buck. The research commenced when each goat was 140 days in lactation and each goat was in the experimental trial for a period of 70 days because of the limited budget available for the study. The experiment started at the beginning of December 2012 until mid-April 2013. The experimental trial started with goats at their mid-lactation stage because there were few local farmers which grow and sell lablab hay; as such it took a long time to find the estimated quantity of lablab hay needed for the whole experimental period. The assumption was that at mid-lactation towards late lactation the goats have already passed the peak of lactation hence increasing the frequency of milking would not increase milk yield.

Twenty-eight lactating Saanen dairy does were selected from Botswana College of Agriculture Dairy Goat Project. Fourteen of the goats were multiparous (2nd, 3rd and 4th lactation) and 14 were primiparous. The goats were intensively managed and housed in individual pens (9.6 m^2) of which 1.7 m^2 had concrete floors and corrugated iron roofs. The goats were vaccinated against pulpy kidney and pasteurella diseases (Pulpy Kidney and Smallstock Pasteurella vaccines, Onderstepoort Biological Products Company, South Africa), dewormed against internal parasites (Ecomectin®, Intervet, South Africa) and dipped for external parasites (Drastic Deadline™, Bayer® animal Health, South Africa) before the start of the experiment. The goats were randomly allocated to two different milking frequencies at their 140th day after parturition and blocked by parity to make them homogenous. Goats were fed a total mixed ration at 4% of their body weight on a dry matter basis daily. In treatment one, 14 animals [seven primiparous and seven multiparous (2nd, 3rd, and 4th lactations) were fed a total mixed ration of lucerne hay as a forage and commercial feed as a concentrate portion, whereas in treatment two 14 animals were fed a total mixed ration with lablab hay as a forage portion while a concentrate portion was a combination of a commercial feed and sunflower cake as shown in Table 4.2. Fresh water was provided *ad libtum*.

Fresh feed offered to the animals was weighed and recorded every morning using CFW-32 electronic platform scale (± 5g, Adam Equipment 2006-Software version V1.04). Half of the feed was offered in the morning at 07:45 hours and another half in the afternoon at 19:45 hours. Removal of orts was done every morning before placement of fresh feed. The orts were collected and weighed to determine the actual daily feed intake. The animals were weighed every two (2) weeks after morning milking before they were given the feed and water to measure their weights and determine their gains or loss. Body weight of the goats was measured using Salter Suspended weigher (200kg±500g - manufactured by Tal-Tec). Parameters recorded were body weight, dry matter intake and milk production. Body condition scoring was not performed because

of limited knowledge and not readily available skilled manpower to assist at the time when this experiment started. All goats were hand milked. In both treatments, seven goats were milked two times a day at 07:00 hours in the morning and 18:00 hours in the afternoon while the remaining seven animals were milked three times a day at 07:00 in the morning, 13:00 hours and 18:00 hours in the afternoon. The experimental trial lasted for a period of 70 days.

4.5.3.1. Experimental design

The experimental design was a 2x2 Factorial in a Randomized Complete Block Design with seven replications. The factors were milking frequency and feed. Each factor had two levels (feed = lucerne ration and lablab ration), (milking frequency = two times and three times daily milking).

4.5.3.2. Milking routine

Before milking, the teats of each goat were cleaned with luke-warm water to remove debris. A California mastitis test (CMT) was performed before starting to milk to identify those animals that may have mammary infections so that they can be treated as early as possible. Fortunately, there were no animals that tested positive for mastitis throughout the experimental period. Goat teats were pre-dipped into 7% iodine solution and wiped-off with a clean paper towel before milking. All goats were hand milked. After milking, udder teats were post-dipped into 7% iodine solution to prevent any infections from entering the mammary glands through the teat canal.

4.5.3.3. Milk sampling

Milk sample from each goat was taken from a composite sample (mixing morning and afternoon milk) and was collected in clean and sterile 50 mL plastic bottles which was then placed in a cooler box at around 4°C and transported to Botswana National Veterinary Laboratory (BNVL) within 24 hours and analysed for chemical composition on arrival date. Sampling procedure was accompanied by a statement which included individual identification and date of harvest. Milk sampling for chemical composition was done on a weekly basis on the same day. Milk yield (kg) of individual animals was measured on a daily basis using CFC-32 electronic plat-form measuring scale (± 5g, Adam Equipment 2006-Software version V1.04) throughout the experimental period.

4.5.3.4. Milk composition analysis

Milk samples were analysed for the content of fat, protein and lactose using milkoscan FT 120 (Model IDF 79) and somatic cell count using electronic particle counter method (BOS ISO 13366 part 2, 1997) at Botswana National Veterinary Laboratory (Test method used, BNVL/MS.WI0040 DH).

4.5.4. Statistical analysis

Data were analysed using the procedure General Linear Model in Statistical Analysis System (SAS) (SAS, 2004) using model 1. The reported least squares means were separated using Least Significant Difference test method (SAS, 2004). Significance was declared at $P<0.05$.

4.5.4.1. Experimental model:

$Y_{ijkl} = \mu + r_i + A_j + B_k + (AB)_{jk} + e_{ijkl}$ …….Model 1

Where;

Y_{ijkl} = response variable,

μ = general mean,

r_i = i^{th} block effect of parity, (primiparous and multiparous)

A_j = j^{th} factor (A) of feed effect, (Lucerne and lablab rations)

B_k = k^{th} factor (B) of milking frequency effect, (two times and three times daily milking)

$(AB)_{jk}$ = interaction of the feed and milking frequency effect,

e_{ijkl} = random variation $\mathbf{N}\sim (0, \alpha/2)$

4.6. Results and Discussion

4.6.1. Body weight gain

Body weight gain was significantly different between the experimental treatments (Table 4.4). Body Condition Score may influence the feed intake and metabolism (Mushtaq *et al*., 2012). De Souza *et al*. (2014) mentioned that high-yielding goats during early lactation require great amounts of energy when the feed intake capacity is limited, which results in the animals mobilizing their body energy reserves. The authours further emphasised that, it is important to provide lactating goats with palatable feed containing a high energy density. Saanen dairy goats as one of the breeds which have long been selected for milk production, their metabolism is entirely under a homeorrhetic control whereby body resources are mobilized at the expenses of other processes for the solely objective to support the on-going galactopoiesis (Pambu *et al*., 2011).

Table 4.4: Average body weight changes (kg/d) of mid-lactating Saanen dairy goats managed under intensive management system and being fed either lucerne or lablab and milked 2x and 3x during 147-210 days postpartum.

Treatments						
Days postpartum	Lucerne 2x LSM (kg/d)	Lablab 2x LSM (kg/d)	Lucerne 3x LSM (kg/d)	Lablab 3x LSM (kg/d)	SEM	LSD or P value
133	57.21[a]	56.65[a]	56.50[b]	56.86[c]	3.06	***
154	57.86[a]	58.93[a]	56.57[b]	56.07[c]	3.06	***
168	56.71[a]	58.07[a]	56.71[a]	55.36[b]	3.06	***
182	57.79[a]	58.79[a]	57.43[a]	56.14[b]	3.06	***
196	58.57[a]	59.57[a]	57.93[a]	56.71[a]	3.06	***
210	59.36[a]	60.36[b]	58.50[c]	57.36[d]	3.06	***

Lucerne 2x = lucerne ration and milked two times a day, lucerne 3x = lucerne ration and milked three times a day, lablab 2x = lablab ration and milked two times a day, lablab 3x = lablab ration and milked three times a day; [abcd] means with the same superscript within a row are significantly different P< 0.05; *** = P<0.0001; LSD = least significance difference; LSM= Least Squares Means, SEM= standard error of the mean.

All goats gained weight between 182 days to 210 days post-partum. This is the period in which lactating goats were approaching the end of lactation, as such milk synthesis from the milk epithelial cells is reduced hence a large portion of the nutrients utilized by the goat is been channelled to body maintenance rather than milk production as it has been realized by a decrease in milk yield during this period. The increased body weight may mean that goats may have been adapted to the experimental rations and conditions as shown by their high dry matter intake during that period. Moreover, since these goats were previously being fed with lucerne and commercial feed separately (not as a total mixed ration), this may have also contributed to their high dry matter intake and increased body weight (for lucerne ration) because lucerne ration was familiar to

them. In addition, the weight changes of these goats was not different from other goats which were not in the experimental group which on average they were weighing 58.38 kg. According to Koyuncu and Altincekic (2013), routine body condition scoring of dairy animals can help detect potential health problems that might cause a decrease in milk production. A flock of goat that is in proper body condition will not only produce more milk, but will also be less susceptible to metabolic disorders, diseases such as mastitis and reproductive problems (Koyuncu and Altincekic, 2013). The body condition score was not performed for this experiment because of limited knowledge. Cimen and Topcu (2013) stated that most researches had shown that larger goats tend to have higher milk yield than lighter goats at early lactation.

4.6.2. Dry matter intake and milk yield

(a) Feeding lucerne and lablab rations

Dry matter intake was significantly higher for mid-lactating Saanen dairy goats fed lucerne based ration (2.49 vs 2.19 kg/d; P=0.0016) than lablab based rations respectively (Table 4.5). These results on dry matter intake were contrary with those of Lee *et al*. (2001) who found that feed intake did not differ significantly among different dietary protein rations on mid-lactating dairy goats. Lee *et al*. (2001) stated that the difference was significant on feed intake only in the first month of lactation period, but not in the second to the fourth month of lactation period of dairy goats. Dairy goats that were used on the current research started experimentation on their fourth month of lactation hence their lactation period corresponds with that of Lee *et al*. (2001). Serment *et al*. (2011) also determined the dietary percentage of concentrate on patterns of dry matter intake, nutrient digestibility, milk production and milk composition in mid-lactating dairy goats. They found that the high amount of concentrate in the diet decreased total dry matter intake and milk yield. This was so because the high amount of concentrate than roughage in the ration makes the ration fine in texture hence may not be appetizing to ruminant animals, therefore they will decrease the intake and consequently milk production drops in case of lactating animals. In this research the addition of sunflower cake to lablab based

ration may somehow had contributed to the high concentrate proportion of the ration hence the lower total dry matter intake and milk yield recorded than the lucerne ration which was basically the mixture of only lucerne hay and commercial concentrate feed.

Table 4.5: Least squares means, standard errors of dry matter intake, milk yield, milk composition and least significant difference of mid-lactating Saanen dairy goats managed under intensive management system and fed lucerne and lablab hay as a total mixed ration during the period 147-210 days postpartum

Parameter	Feeds			
	Lucerne ration LSM (n =14)	Lablab ration LSM (n =14)	SEM	LSD or P value
DMI (kg/d)	2.49[a]	2.19[b]	0.067	0.016
Milk yield (kg/d)	2.51[a]	2.21[b]	0.067	0.016
4% FCM (kg/d)	2.15[a]	1.84[b]	0.049	***
Fat (%)	3.18[a]	2.99[b]	0.055	0.0377
Fat yield (kg/d)	0.08[a]	0.06[b]	0.002	***
Protein (%)	2.86[a]	2.80[a]	0.035	0.2067
Protein yield (kg/d)	0.07[a]	0.06[b]	0.002	***
Lactose (%)	4.17[a]	4.21[a]	0.026	0.1996
Lactose yield (kg/d)	0.11[a]	0.09[b]	0.003	0.0148
ECM (kg/d)	2.71[a]	2.61[b]	0.029	***
EE	1.17[a]	1.40[b]	0.029	***
FE	0.88[a]	0.86[b]	0.008	0.0382
SCS	6.06[a]	5.99[a]	0.029	0.0955

DMI (dry matter intake), FCM (fat corrected milk), ECM (energy corrected milk) EE= energy efficiency, FE= feed efficiency, SCS (somatic cell score = Somatic cell count x1000 $\log_{10}$), SEM = standard error of the mean. Equations: 4% FCM= (0.4 x kg milk) + (0.15 x kg milk x fat %); ECM = (0.327 x kg milk) + (12.95 x kg fat) + (7.2 x kg protein); EE= ECM/DMI; FE= FCM/DMI. Means within the same row have the same SEM. [ab] means with the same superscript within a row are significantly different at $P<0.05$; *** = $P<0.0001$, LSD = least significant difference, LSM = Least Squares Means.

Milk yield was significantly different between feeding lucerne and lablab based rations to these mid-lactating Saanen dairy goats. Goats that were fed lucerne and lablab based rations produced (2.51 vs 2.21 kg/d milk; P=0.0016) respectively (Table 4.5). Lucerne and lablab forages were considered for goat feeds not only because they have higher crude protein content than locally available forages, but they have lower levels of acid detergent fibre. As such they would be better digested and utilized by dairy goats for milk production effectively. Pambu *et al*. (2011) mentioned that fluctuations in the milk yield of dairy animals is subject to much variation within breeds such as, age, stage of lactation, parity, season, location and geographic areas. Morand-Fehr *et al*. (2000) assessed the dietary effects on the fat and protein percentage in milk of intensively kept dairy goats fed mixed complete diets of lucerne hay or dehydrated lucerne blocks at 60% (high) and 30% (low) total dry matter and concentrates. Their results showed that milk yield was significantly higher in low diets limited in roughage (3.48 vs 3.10 kg/d) than for high diets. Harris and Springer, (2005) highlighted that good quality hay and a balanced concentrate mix appear to do well in maintaining high levels of milk production in dairy goats.

(b) Milking twice and three times a day

Dry matter intake (2.60 vs 2.07 kg/d; P<0.0001) were significantly higher for mid-lactating Saanen dairy goats that were milked two times a day than those that were milked three times a day respectively (Table 4.6). This resulted in mid-lactating Saanen dairy goats that were milked twice a day producing 0.53 kg/d more milk than three times a day milking. These results are contrary to that of Akpa *et al*. (2003) who indicated that milk yield increased by 10% when Red Sokoto goats were milked thrice instead of twice a day. Williams *et al*. (2012) also mentioned that increasing milking frequency from two times a day milking (2x) to three times a day milking (3x) increased milk yield by 7 to 20% in West African Dwarf goats. The reason why the milk yield in the current research did not increase as the frequency of milking was increased from

two times to three times daily milking may be due to the fact that the interval between three times daily milking was much shorter (6 hours interval) instead of eight hours interval per day as for other researches. It may also be affected by the fact that goats on three times daily milking were frequently disturbed with the milking at the time when they were supposed to be feeding and ruminating. That is, the nutrients absorbed in to the blood stream within the shorter intervals of milking were insufficient to allow the milk secreting cells to produce enough milk, considering the fact that at mid-lactation towards the end of lactation milk secreting cells decrease in size and number. According to Wall and McFadden (2012) regular and complete removal of milk from the mammary gland in lactating animals is critical for maintaining milk production. Chedly *et al*. (2012) mentioned that the reduction in milk yield from two times a day to once a day milking in lactating dairy cows may range between 6 to 40 % due to different factors such as parity level, stage of lactation and animal breed.

Table 4.6: Least squares means, standard errors of dry matter intake, milk yield, milk composition and least significant difference of mid-lactating Saanen dairy goats managed under intensive management system and milked two times and three times a day during the period 147-210 days postpartum

Parameter	Milking Frequency			
	Two times a day LSM (n =14)	Three times a day LSM (n = 14)	SEM	LSD or P value
DMI (kg/d)	2.60[a]	2.07[b]	0.067	***
Milk yield (kg/d)	2.65[a]	2.10[b]	0.068	***
4% FCM (kg/d)	2.18[a]	1.81[b]	0.050	***
Fat (%)	2.97[a]	3.20[b]	0.055	0.0037
Fat yield (kg/d)	0.08[a]	0.06[b]	0.002	***
Protein (%)	2.74[a]	2.92[b]	0.035	0.0002
Protein yield (kg/d)	0.07[a]	0.06[b]	0.002	***
Lactose (%)	4.23[a]	4.15[b]	0.026	0.0385
Lactose yield (kg/d)	0.11[a]	0.09[b]	0.003	***
ECM (kg/d)	2.75[a]	2.57[b]	0.022	***
EE	1.16[a]	1.41[b]	0.029	***
FE	0.85[a]	0.89[b]	0.008	0.0036
SCS	6.07[a]	5.99[a]	0.030	0.0641

DMI (dry matter intake), FCM (fat corrected milk), ECM (energy corrected milk) EE= energy efficiency, FE= feed efficiency, SCS (somatic cell score = Somatic cell count x1000 $\log_{10}$), SEM = standard error of means; Means within the same row have the same SEM; Equations: 4% FCM= (0.4 x kg milk) + (0.15 x kg milk x fat %); ECM = (0.327 x kg milk) + (12.95 x kg fat) + (7.2 x kg protein); EE= ECM/DMI; FE= FCM/DMI; [ab] means with the same superscript within a row are significantly different $P< 0.05$; *** = $P < 0.0001$; LSD = least significance difference; LSM= Least Squares Means.

(c) Interaction of feeds and milking frequencies

Dry matter intake was significantly higher in goats that were fed lablab ration and milked two times a day (2.72 kg/d; $P < 0.0001$) while those that were fed lablab ration and milked three times a day had a significantly lower dry matter intake (1.78 kg/d; $P < 0.0001$) than other treatment combinations (Table 4.7). Overall results had shown that animals that were milked three times a day consumed less feed than goats that were milked twice a day. This may be due to the fact that goats on 3x milking were disrupted with the milking when they were supposed to be feeding or ruminating. Furthermore, average daily milk yield was significantly higher (2.75 kg/d; $P < 0.0001$) for goats that were fed lablab ration and milked two times a day while goats that were fed lablab ration and milked three times a day yielded significantly lower milk yield (1.80 kg/d; $P < 0.0001$). The relationship between milk production and dry matter intake was almost directly proportional. Similar results under semi-arid conditions in Mexico and India showed that the milk yield of goats is positively related to dry matter intake (Timon and Hanrahan, 1985).

Table 4.7: Average dry matter intake (kg/d), milk yield (kg/d) and milk composition of mid-lactating Saanen dairy goats managed under intensive management system and being fed Lucerne or Lablab and milked two times (2x) and three times (3x) a day during 147-210 days postpartum.

Parameter	Lucerne 2x (n=7)	Lablab 2x (n=7)	Lucerne 3x (n=7)	Lablab 3x (n=7)	SEM	LSD or P value
DMI(kg/d)	2.61^{a}	2.72^{a}	2.25^{b}	1.78^{c}	0.107	***
Mlkyld (kg/d)	2.63^{a}	2.75^{a}	2.27^{b}	1.80^{c}	0.108	***
4% FCM (kg/d)	2.19^{ab}	2.27^{a}	2.01^{b}	1.50^{c}	0.089	***
Fat (%)	2.96^{a}	2.95^{a}	3.40^{b}	3.03^{a}	0.071	***
Fatyld (kg/d)	0.08^{a}	0.08^{a}	0.08^{a}	0.05^{b}	0.003	***
Protein (%)	2.80^{b}	2.63^{c}	2.98^{a}	2.92^{ab}	0.045	***
Prtnyld (kg/d)	0.07^{a}	0.07^{a}	0.07^{a}	0.05^{b}	0.002	***
Lactose (%)	4.18^{a}	4.29^{b}	2.14^{a}	4.15^{a}	0.085	***
Lactseyld (kg/d)	0.11^{a}	0.12^{a}	0.09^{b}	0.07^{c}	0.037	***
ECM (kg/d)	2.75^{a}	2.79^{a}	2.63^{b}	2.47^{c}	0.005	***
EE	1.11^{c}	1.16^{c}	1.28^{b}	1.59^{a}	0.126	***
FE	0.85^{a}	0.85^{a}	0.92^{b}	0.86^{a}	0.015	***
SCS	6.18^{a}	5.98^{b}	5.92^{b}	6.03^{b}	0.014	***

DMI =dry matter intake, mlkyld = milk yield, FCM = fat corrected milk, Fatyld= fat yield, Prtnyld= protein yield, Lactseyld= lactose yield, ECM = energy corrected milk, EE= energy efficiency, FE= feed efficiency, SCS (somatic cell score = Somatic cell count x1000 $\log_{10}$), Lucerne 2x = lucerne ration and milked two times a day, lucerne 3x = lucerne ration and milked three times a day, lablab 2x = lablab ration and milked two times a day, lablab 3x = lablab ration and milked three times a day, SEM = standard error of means; ^{abc} means with the same superscript within a row are significantly different $P < 0.05$; *** = $P < 0.0001$; LSD= Least significant difference, Equations: 4% FCM= (0.4 x kg milk) + (0.15 x kg milk x fat %), ECM = (0.327 x kg milk) + (12.95 x kg fat) + (7.2 x kg protein), EE= ECM/DMI, FE= FCM/DMI.

Dry matter intake progresively decreased from day 147 to 210 days post-partum (Table 4.8). According to Tarr and Leaf (2011), dry matter intake (DMI) ussually peaks between 8 to 12 weeks postpartum and it is affected by parity and breed. Saanen dairy goats that were used in the current research were about 20 weeks postpartum as such their decrease in DMI agrees with results of Tarr and Leaf (2011). These results were in line with that of Galina *et al*. (1995) who indicated that confined dairy goats during mid-lactation when fed 45% of concentrates and lucerne hay of 1.9 Mcal/DM were able to consume as much as 6% dry matter (DM) of their body weight. Tarr and Leaf (2011) indicated that dry matter intake (DMI) tends to increase with increasing dietary protein level but decrease with increasing energy density. Therefore, the energy density of the ration, milk production and body weight are the variables that are normally used to predict the DMI of goats.

Table 4.8: The average dry matter intake (kg/d) of mid-lactating Saanen dairy goats managed under intensive management system and being fed Lucerne or Lablab and milked 2x and 3x a day during 147-210 days postpartum.

	Treatments					
Days postpartum	Lucerne 2x (kg/d)	Lablab 2x (kg/d)	Lucerne 3x (kg/d)	Lablab 3x (kg/d)	SEM	LSD or P value
147	2.97^{a}	3.25^{a}	2.94^{b}	2.33^{c}	0.17	***
154	2.84^{a}	3.19^{b}	2.89^{c}	2.27^{d}	0.17	***
161	2.71^{a}	2.94^{a}	2.64^{b}	2.03^{c}	0.17	***
168	2.81^{a}	2.66^{a}	2.45^{a}	1.87^{b}	0.17	***
175	2.56^{a}	2.55^{a}	2.33^{a}	1.56^{b}	0.17	***
182	2.56^{a}	2.54^{a}	2.34^{a}	1.61^{b}	0.17	***
189	2.45^{a}	2.54^{a}	2.14^{b}	1.53^{c}	0.17	***
196	2.36^{a}	2.47^{a}	2.23^{a}	1.45^{b}	0.17	***
203	2.21^{a}	2.37^{a}	2.16^{a}	1.30^{b}	0.17	***
210	1.95^{a}	2.01^{a}	2.04^{a}	1.25^{b}	0.17	***

Lucerne 2x = lucerne ration and milked two times a day, lucerne 3x = lucerne ration and milked three times a day, lablab 2x = lablab ration and milked two times a day, lablab 3x = lablab ration and milked three times a day, SEM = standard error of means; ^{abc} means with the same superscript within a row are significantly different $P< 0.05$; *** = $P < 0.0001$; LSD= Least significant difference.

Milk yield progressively declined from the 147th day to the 210th day postpartum in all the four treatment combination. The results on Table 4.8 showed that goats that were fed lablab ration and milked two times a day had a higher dry matter intake and as such they produced higher milk yield than goats that were fed lucerne ration and milked three times a day (Table 4.9). Generally, milk production is largely dependent on the shape of the lactation curve. Cannas *et al*. (2013) noted that relevant elements of the lactation pattern are the peak yield, which represents the maximum milk yield during the lactation, and the lactation persistency,

which expresses the ability of animals to maintain a reasonably constant milk yield after the lactation peak. Tarr and Leaf (2011) indicated that goats peak milk yield at 6 to 8 weeks into lactation and thereafter decline at a rate of between 10 – 15% towards late lactation. Pambu *et al*. (2011) highlighted that milk production in dairy goats depends on numerous factors in production and feeding and their interactions could influence milk yield and composition. Breed, parity and stage of lactation affect milk production (Tarr and Leaf, 2011). The decline in milk yield in the current research was due to the fact that these experimental goats started the trial at their mid-lactation stage hence they had passed the peak of lactation and approaching late lactation which from the lactation curves it is the point where milk production decreases.

Table 4.9: The average milk yield (kg/d) of mid-lactating Saanen dairy goats managed under intensive management system and being fed Lucerne or Lablab and milked 2x and 3x a day during 147-210 days postpartum.

Treatments						
Days postpartum	Lucerne 2x LSM (kg/d)	Lablab 2x LSM (kg/d)	Lucerne 3x LSM (kg/d)	Lablab 3x LSM (kg/d)	SEM	LSD or P value
147	3.00^{a}	3.29^{a}	2.97^{b}	2.35^{c}	0.17	***
154	2.87^{a}	3.22^{b}	2.92^{c}	2.30^{d}	0.17	***
161	2.74^{a}	2.97^{a}	2.67^{b}	2.05^{c}	0.17	***
168	2.84^{a}	2.69^{a}	2.47^{a}	1.88^{b}	0.17	***
175	2.59^{a}	2.58^{a}	2.36^{a}	1.57^{b}	0.17	***
182	2.59^{a}	2.56^{a}	2.37^{a}	1.63^{b}	0.17	***
189	2.48^{a}	2.57^{a}	2.17^{b}	1.55^{c}	0.17	***
196	2.39^{a}	2.49^{a}	2.26^{a}	1.46^{a}	0.17	***
203	2.23^{a}	2.39^{a}	2.18^{a}	1.31^{b}	0.17	***
210	1.97^{a}	2.03^{a}	2.18^{a}	1.26^{b}	0.17	0.30

Lucerne 2x = lucerne ration and milked two times a day, lucerne 3x = lucerne ration and milked three times a day, lablab 2x = lablab ration and milked two times a day, lablab 3x = lablab ration and milked three times a day, SEM = standard error of means; ^{abc} means with the same superscript within a row are significantly different $P< 0.05$; *** = $P < 0.0001$; LSD= Least significant difference.

4.6.3: Milk composition

(a) Feeding lucerne and lablab rations

Fat yield was significantly different between feeding lucerne and lablab rations to mid-lactating Saanen dairy goats (0.08 vs 0.06 kg/d; $P<0.0001$). However, four per cent (4%) fat corrected milk (2.15 vs 1.84 kg/d; $P<0.0001$), fat percentage (3.18 vs 2.99 %; $P=0.0377$) and fat efficiency (0.88 vs 0.86; $P=0.0382$) were significantly higher for goats that were fed lucerne ration than goats that were fed lablab ration respectively

(Table 4.5). These parameters are important in the dairy industry more especially in Africa because milk is sold as per volume basis hence the relevance of identifying high-milk yielding goats. Futhermore, the dairy industry pays a premium for milk fat and milk proteins concentrations as these technically reflect the milk quality (Pambu *et al*., 2011). Chilliard *et al*. (2003) mentioned that in lactating animals such as goats, milk fat content tends to be higher after parturition and then decreases as lactation period progresses. The variation in milk fat content during lactation is related to a dilution effect due to the increase in milk volume until peak of lactation, and a decrease in fat mobilization that decreases the availability of plasma Non-Estrified Fatty Acids (NEFA) (Chilliard *et al*., 2003). Fekadu *et al*. (2005) stated that goat milk is of great economic concern to producers, manufacturers and consumers in production of cheese of certain composition, yield and quality, as such, milk fat and protein was highly correlated with the yield of hard cheese.

The high milk fat percentage of goats that were fed lucerne ration may be atributed to the fact that goats that were fed lucerne ration consumed more feed hence high amount of dietary fibre eaten which may have contributed to the higher fat percentage than for goats that were fed lablab rations. Qudus *et al*. (2013) mentioned that the level of dietary fibre consumed positively increase milk fat percentage in lactating ruminants. The results on the current research was less than those of Brito *et al*. (2011) who found that the average value for Saanen dairy goat milk fat at 270 days of lactation to be 3.74%. Guo *et al*. (2004) indicated that the main chemical constituents of goat milk are high in early lactation stage, rapidly decrease, and then remain low during mid-lactation stage, and increase again towards late lactation or the end of lactation. Variations in weather, feed quality and quantity, ration particle size, genetics, and stage of lactation are among the factors which influence the average percentage of goat milk fat (Bruhn, 1996; Brito *et al*., 2011).

Protein yield was significantly higher for mid-lactating Saanen dairy goats fed lucerne based ration (0.07 vs 0.06%; P<0.0001) than lablab based rations respectively. Furthermore, protein percentage was not significantly different between goats that were fed lucerne based ration (2.87 vs 2.80%; P= 0.2067) than goats that were fed lablab based rations respectively (Table 4.5). Lock and Van Amburgh (2012) stated that in dairy cows an increase in milk protein content can be achieved by feeding of high starch concentrates, and to a lesser extent with protein supplements. In addition, Serment *et al*. (2011) found protein yield to be greater in goats that were fed high concentrate diets. However the scope to alter milk protein content is rather limited and much lower than that of milk fat (Lock and Van Amburgh, 2012).

Lactose percentage (4.17 vs 4.21%; P=0.1996) did not differ significantly between feeding lucerne and lablab based rations to mid-lactating Saanen dairy goats respectively. Lactose yield (0.11 vs 0.09 kg/d; P= 0.0148) was significantly higher for goats that were fed lucerne based ration than lablab based ration respectively (Table 4.5). The results on lactaose percentage were in line with what have been reported by Guo *et al*. (2004) that the content of lactose does not depend on the stage of lactation. Moreover, Park *et al*. (2007) stated that towards the end of the lactation lactose content decreases. Pambu *et al*. (2011) indicated that lactose is the most stable constituent of the goats milk. Therefore, when milk lactose concentration goes down it signals infection in the mammary gland and when increases it may imply a decrease in feed intake or a severe heat exposure (Pambu *et al*., 2011). The current results were lower than that of Mba *et al*. (1975) who found that mean milk lactose contents of Saanen was 4.56% at mid-lactation stage. In addition, Nagy and Nikodemusz (1997) determined lactose concentration in the milk of Saanen goats fed a milking concentrate and lucerne hay during the 5^{th} to the 7^{th} month of lactation and found overall lactose concentrations of 4.7%.

Energy corrected milk and energy efficiency were significantly different between feeding lucerne and lablab rations to mid-lactating Saanen dairy goats. Energy Corrected Milk of mid-lactating Saanen goats that were fed lablab based ration was significantly lower (2.71 vs 2.61 kg/d; P<0.0001) than goats that were fed lucerne ration. Energy efficiency was significantly higher for goats that were fed lablab based ration (1.40 vs 1.17; P<0.0001) than of goats that were fed lucerne based ration respectively (Table 4.5). Energy Corrected Milk (ECM) is the expression of the amount of energy in milk based upon weight of milk, fat and protein standardized to 3.5% and 3.2% fat and protein respectively. Bernard (1997) also found no differences for the production of energy-corrected milk when determining the effect of the source of supplemental protein in diets containing wheat middlings on milk production and composition of dairy cows.

(b) Milking twice and three times a day

Milk fat percentage of goats that were milked two times a day was found to be 0.23 per cent significantly lower than of goats that were milked three times a day (2.97 vs 3.20%; P= 0.0.0037) respectively. However, 4% fat corrected milk (4% FCM) of goats that were milked two times a day was significantly higher (2.18 vs 1.81%; P<0.0001) than of goats that were milked three times a day (Table 4.6). The results of the current research were in contrast to that of Salama *et al*. (2003) who found that once daily milking resulted in an 18% reduction in the yield of 4% fat-corrected milk compared to twice daily milking of Murciano-Granadina dairy goats. The authors further mentioned that the reduction in 4% fat corrected milked was more recorded between week 2 to week 12 postpartum than in mid and late lactation stages. Nudda *et al*. (2000) found that milk fat content did not differ significantly between once daily milking and twice daily milking (6.69 vs 6.44%; P≥0.10 7.48 vs 6.86%; P≥0.10 and 8.31 vs 7.64%; P≥0.10) for udder halves in Sarda, Awassi and Merino sheep at mid-lactation stage respectively. Research by Taylor (2006) had shown that milking dairy cows twice-a-day (2x) produced a higher fat percentage compared to three times a day (3x). In addition,

increasing milking frequency to 3x, resulted in greater fat yield than 2x. Protein percentage was significantly higher (2.92 vs 2.74%; P=0.0002) for goats that were milked three times a day as compared to goats that were milked two times a day at respectively (Table 4.6). Taylor (2006) indicated that increasing milking frequency in dairy cows produced lower protein levels in milk.

Energy corrected milk (ECM) of goats that were milked two times a day was significantly higher (2.75 vs 2.57 kg/d; P<0.0001) than goats that were milked three times a day (Table 4.6). This was due to the fact that goats that were milked two times a day had a higher dry matter intake which they utilized efficiently to produce higher milk yield as compared to goats that were milked three times a day. Gardner and Hogue (1966) mentioned that lactating animals should be offered adequate energy from the feed so that they can use energy efficiently to prevent weight losses during lactation and produce to their maximum milking potential. Energy corrected milk yield (ECM) accounts for the true protein content of milk and determines the amount of energy in the milk based upon milk fat and milk protein. The ECM could be considered as criterion for the energy status of lactating animals (Hossein-Zadeh, 2012).

Somatic cell score (SCS) did not differ significantly between milk of goats that were milked two times and three times a day. SCS of milk of goats that were milked two times a day washigher (6.07 vs 5.99 Log_{10}cells/ml; P= 0.0641) than of goats that were milked three times a day respectively (Table 4.6). These results are in agreement with those of Shields *et al*. (2011) who reported that increasing milking frequency from two times to four times daily did not increase milk total somatic cell score. Increased milking frequency was also found by Taylor (2006) to improve udder health status, with lower somatic cell counts (SCCs) observed for 3X compared to 2X in dairy cows. Hand milking in the current research may have contributed to the high somatic cell scores. Rupp *et al*. (2011) mentioned that the range of somatic cell score ussually

reported in dairy goats is between 5.1 and 5.3 Log_{10}cells/ml. In addition, Ontario Ministry of Agriculture and Food (2010) mentioned that somatic cell score levels in goat milk tend to be elevated towards the end of lactation.

In this experimental trial the animals finished the research nearly towards the end of lactation hence the higher somatic cell score found on this reseacrch agree with that of Ontario Ministry of Agriculture and Food (2010). Nudda *et al*. (2000) found that the somatic cell score was influenced by milking treatment in the Sarda ewes, with high values observed in the milk of once daily milking (2.38 vs 2.01 Log_{10}cells/ml; $P<0.05$) as compared to twice daily milking udder halves. The authors further observed the insignificant difference in the Awassi and Merino sheep (1.90 vs 1.80 Log_{10}cells/ml; $P\geq0.10$ and 2.07 vs 1.79 Log_{10}cells/ml; $P\geq0.10$) respectively. However, Barron-Bravo *et al*. (2013) mentioned that in goats, the ability of somatic cell score in milk to predict intra mam-mary infection is lower than in dairy cows because of the presence of many cytoplasmic particles resulting from apocrine milk secretion.

(c) Interaction of feeds and milking frequencies

Four per cent fat corrected milk (4 % FCM) was significantly higher for goats that were fed lablab ration and milked two times a day, whereas goats that were fed lablab and milked three times a day had significantly lower 4% fat corrected milk. In addition, milk fat content was higher (3.40%; $P<0.0001$) for goats that were fed lucerne and milked three times a day while the least percentage of milk fat was found on goats that were fed lablab and milked two times a day (2.95%; $P<0.0001$) (Table 4.6). Bava *et al*. (2001) mentioned that dietary fibre is important to ruminants as it maximizes dry matter intake (DMI) and stimulate chewing activity and rumen fermentation. Neutral detergent fibre (NDF) maintains a satisfactory milk fat content and fat corrected milk (FCM) yield. This role of fibre is strongly influenced by the dimensions of the feed

particles and their retention time in the rumen (Bava *et al*., 2001). Lucerne based ration was more fibrous than lablab based ration as such their retention time in the rumen was higher hence their higher percentage of milk fat than that of lablab based ration. In addition, Torri *et al*. (2004) highlighted that the variations in fat content of dairy goats were related to different factors, such as lactation stages, temperature, and quantity of milk produced, breed and feed type.

Milk protein content was significantly higher (2.98%; $P<0.0001$) in goats that were fed lucerne ration and milked three times a day while goats that were fed lablab ration and milked two times a day had significantly lower content of milk protein (2.63%; $P<0.0001$). The protein content was within the normal range for goat milk which was reported by Hejtmankova *et al*. (2012). Boro *et al*. (2008) when studying the factors which affect goat milk yield and milk composition found that milk protein content tended to increase with the progression of lactation period in Alpine and Saanen goats. However, the results were lower than those reported by Torri *et al*., (2004) when studying protein content of the Saanen and Parda dairy goat milk, found average values of 3.11 (g/100g), and when studying the milk chemical composition of Alpine, Nubian, Toggenburg and Saanen breeds, found average values of protein around 3.25%. In addition, Amills *et al*. (2012) mentioned that milk protein and fat contents normally vary between breeds and due to environmental factors.

Lactose percentage was significantly higher for goats that were fed lablab ration and milked two times a day (4.29%; $P<0.0001$) followed by goats that were fed lucerne ration and milked two times a day (4.18%; $P<0.0001$) while goats that were fed lucerne ration and milked three times a day significantly had a lower lactose content (4.14%; $P<0.0001$). On average, the results were in line with that of Torri *et al*., (2004) who found the lactose content of Saanen dairy goat milk average of 4.17%. Olechnowicz and Sobek (2008)

mentioned that lactose content in goat milk decreased with progression of lactation period. Kralickova *et al*. (2012) also reported balanced lactose content during entire lactation of Brown short-haired goats.

Goats that were fed lablab ration and milked two times a day had a higher energy corrected milk (ECM) (2.79 kg/d; $P<0.0001$) while goats that were fed lablab ration and milked three times a day had a lower energy corrected milk yield (2.47 kg/d: $P<0.0001$). However, energy efficiency (EE) was significantly higher for goats that were fed lablab ration and milked three times a day (1.59; $P<0.0001$) while goats that were fed lucerne ration and milked two times a day had significantly lower energy efficiency (1.11; $P<0.0001$). Feed efficiency (FE) was significantly higher in goats that were fed lucerne ration and milked three times a day (0.92; $P<0.0001$) followed by goats that were fed lablab ration and milked two times a day (0.86; $P<0.0001$) while FE was significantly lower in goats that were fed lucerne ration and milk two times a day (0.85; $P<0.0001$) and goats that were fed lablab ration and milked three times a day (0.85; $P<0.0001$) (Table 4.6). Torri *et al*. (2004) reported that utilization of different protein sources in concentrate plus lucerne hay as roughage and is important in the diet of dairy goats for the production and composition of milk. Feed efficiency (FE) is the kilograms of milk produced per kilogram of dry matter (DM) consumed (Hutjens, 2005). Feed to gain ratio had been used in beef, swine, fish, and poultry industries as a benchmark for profitability (Hutjens, 2005).

4.6.4. Production cost estimates of feeding either lucerne or lablab rations to Saanen dairy goats milked twice or three times a day at mid-lactation stage.

The production costs estimates were computed on average of one milking goat per the experimental period. The price of buying a bale of lucerne and lablab hay was the same for this study while other costs were different. Feed costs were calculated based on the ratios of feed ingredient as per each ration and the amount

of dry matter consumed (Table 4.10). On average feeding lablab ration to mid-lactating Saanen dairy goats and milking them two times a day produced more profit as compared to other treatment combinations while feeding lucerne ration and milking three times a day produced less profit.

Table 4.10: Production cost estimates of feeding mid-lactating Saanen dairy goats lucerne and lablab rations and milking 2x and 3x a day at 147th -210th day postpartum

Feed	Lucerne ration		Lablab ration	
Milking frequency	2x	3x	2x	3x
Parameter				
Average milk yield/goat/day (kg)	2.63	2.27	2.75	1.80
Total milk (kg) for 70 days/goat	184.10	158.90	192.50	126.00
Milk income @P16/kg/goat	**P2945.60**	**P2542.40**	**P3080.00**	**P2016.00**
Total DMI, kg/goat	182.70	157.50	190.40	124.60
Feed cost /goat	P91.30	P86.90	P95.25	P61.80
Labour cost @ P10.83/hr./goat	P569.03	569.03	P569.03	P569.03
Veterinary expenses /goat	P22.10	P22.10	P22.10	P22.10
Miscellaneous costs/goat	P80.50	P80.50	P80.50	P80.50
Total costs /goat	**P762.93**	**P758.53**	**P766.88**	**P733.43**
Gross margin/goat	**P2182.67**	**P1783.87**	**P2313.12**	**P1282.57**

Where: feed cost = {cost of hay @P3.75/kg * % hay * total DMI} + {cost of concentrate @P3.46/kg * % concentrate * total DMI} + {cost of sunflower cake@P3.78/kg * % sunflower cake* total DMI}. Cost of labour = [rate/hr. *hours worked*70 days]/ 4. Veterinary expenses = {cost of pasteurella vaccine @ P2.50/2ml + cost of pulpy kidney vaccine @ P1.40/1ml + cost of oral dewormer @ P18.20/10ml}. Miscellaneous costs = {cost of iodine solution @ P1/10ml + cost of Mastitis test solution @ P0.50/0.5ml) Gross margin = milk income – total costs. (Exchange rate used: US$1= P6.995 at the time of study).

The high profit produced was due to the high amount of milk produced by the goats that were fed lablab ration and milked two times a day while goats that were fed lucerne ration and milked three times a day produced less milk than all other groups. Feed costs account for a larger percentage of livestock expenses, accounting for more than 55% of dairy goat production costs (Van Saun, 2000). The reduction in feed costs in dairy production increases profit margins. The more milk the goat produces and the greater the feed efficiency the more profit will be realized (Van Saun, 2000). Increasing the frequency of milking per day is regarded as an effective management tool that allows dairy goat farmers to increase milk production efficiency. McFadden and Wall (2010) stated that the profitability of increased milking frequency is recognized when the value of the extra milk produced exceeds the costs associated with the extra milkings. The authors further mentioned that with adequate management, the profitability of adopting three times daily milking also depends on labour and other costs as well as current milk prices.

4.7. Conclusions

Feeding the lucerne based ration promoted higher dry matter intake which had resulted in high milk production than feeding the lablab based ration because of the high levels of acid detergent fibre in the forage. Milk composition was significantly influenced by feeding either lucerne or lablab based rations. Milking two times a day produced higher milk yield than three times a day milking. This was so because overall results had shown that animals that were milked three times a day consumed less feed than goats that were milked twice a day. Moreover, milking frequency had a significant effect on milk composition of Saanen dairy goats.

The interaction of feeding lablab or lucerne based ration and milking twice or three times a day significantly influenced milk production. The interaction of feeding either lucerne or lablab rations and milking frequency influenced milk composition of mid-lactating Saanen dairy goats. Milk production is largely dependent on the shape of the lactation curve. If complete lactations had been measured, these goats could have peaked milk yield between 6 to 8 weeks into lactation and thereafter decline towards late lactation. In addition, if the number of goats used was equal or greater than 30, statistically the results would be considered valid and more informative. More estimated profit was observed on goats that were fed lablab based ration and milked two times a day for this limited experiment. The high profit produced was due to the high amount of milk produced by the goats.

4.8. Recommendations

Local dairy goat farmers should be encouraged to feed their animals with lablab based rations since they can produce more milk at a lower cost. Farmers can adopt milking their dairy goats two times a day because it has been shown to produce more milk than three times daily milking although this result was different from those reported in other researches. Another project should be done to include the entire lactation and performed at different ecological environments to factor in the effects of seasonal and environmental variations on dry matter intake, milk yield and milk composition of Saanen goats. These may influence the results because literature had showed that the composition of the milk produced by a given breed depends on the lactation state and only if feeding and environmental conditions are adequate.

CHAPTER FIVE

5.0. General conclusion

The first study indicated that the situation of dairy goat production in Botswana is at its infancy stage. Dairy goats were allowed to roam around the fields during the day to browse and they were brought back to their kraals in the late afternoon to be given available supplements and water. The commonly available supplements for dairy goats included lucerne or lablab hay, commercial concentrates and sorghum bran. Dairy goat farmers are normally practising a partial suckling system where by kids are separated from their mothers at night and milking is done in the morning. They then allow the kids to suckle from their dams during the afternoon when the goats return from grazing areas. Farmers are keeping dairy goats for daily household milk consumption and selling the surplus milk for household income.

Regular milking and feeding high quality total mixed rations such as lucerne and lablab based rations to dairy goats is likely to increase daily flock milk production locally and help reduce high costs of milk imports. It was found that feeding goats with lucerne based rations produced higher milk yield than feeding lablab based mixed rations. In addition, milking mid-lactating Saanen goats twice a day promoted higher milk yield as compared to three times a day milking. More estimated profit was realized on goats that were fed lablab based ration and milked two times a day but the high estimated profit observed was due to the high amount of milk produced by goats on this treatment combination as compared to others.

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APPENDIX

Figures for feeding experiment (study two)

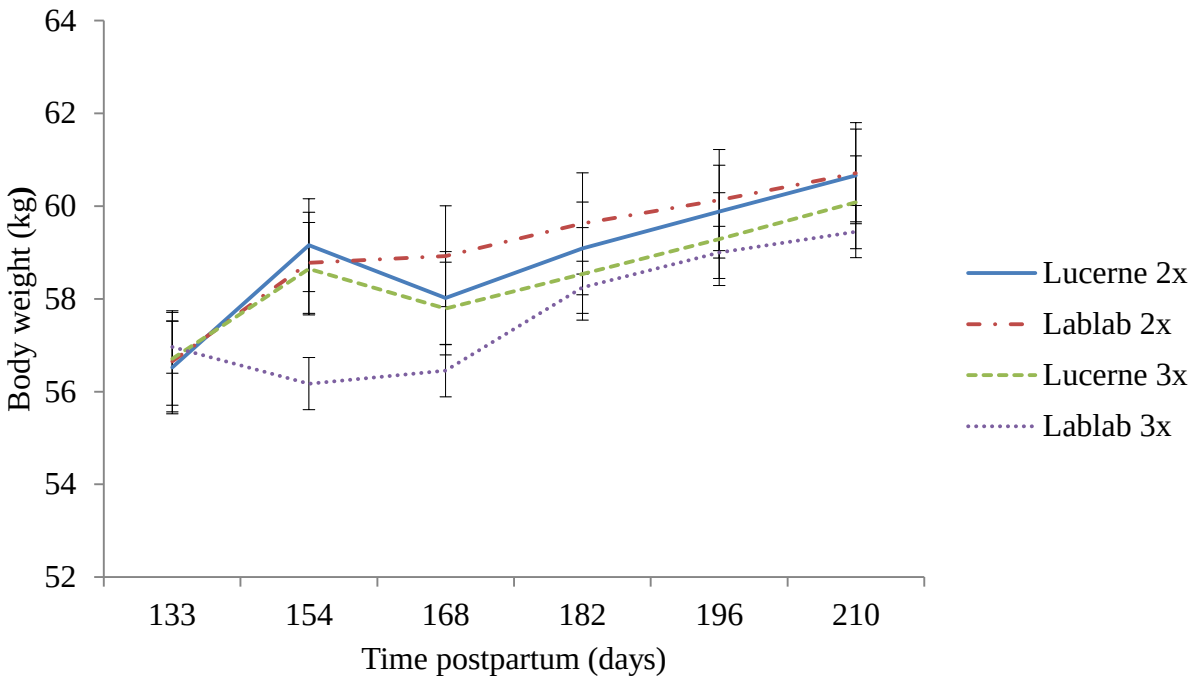

Figure 4.1: Average body weight changes (kg) of mid-lactating Saanen dairy goats managed under intensive management system and being fed either lucerne or lablab and milked 2x and 3x during 147-210 days postpartum.

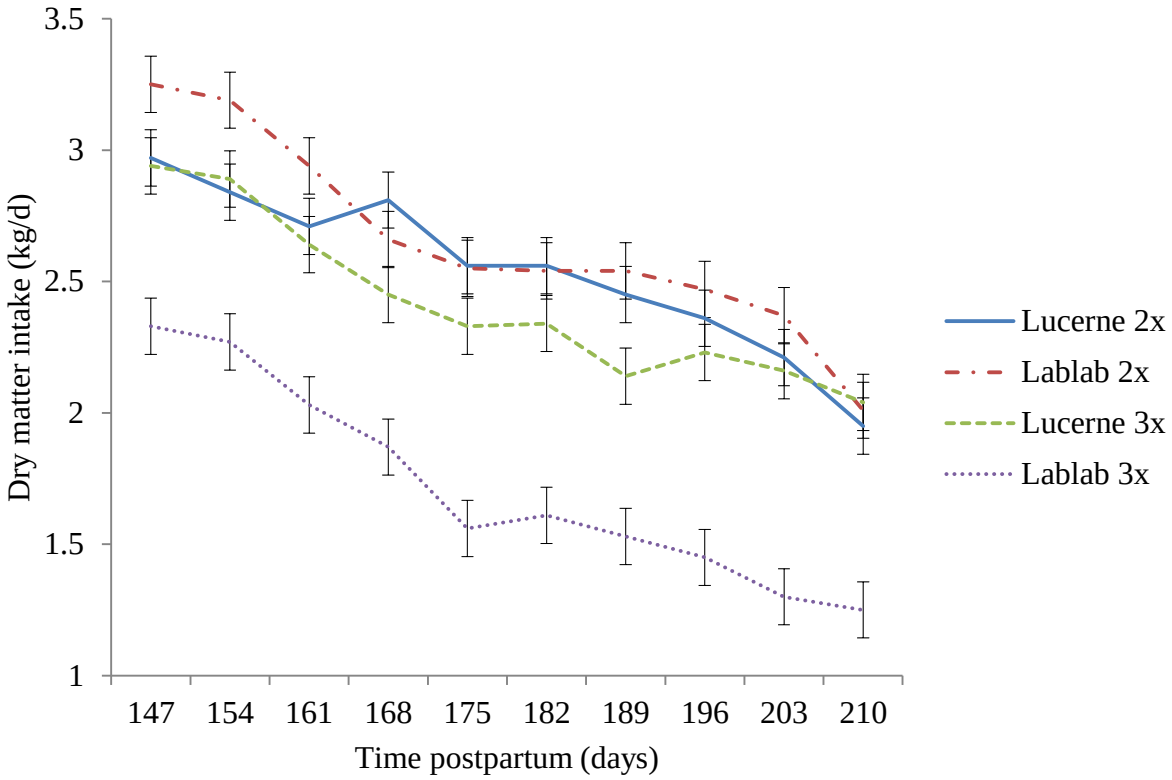

Figure 4.2: The average dry matter intake (kg/d) of mid-lactating Saanen dairy goats managed under intensive management system and being fed Lucerne or Lablab and milked 2x and 3x a day during 147-210 days postpartum.

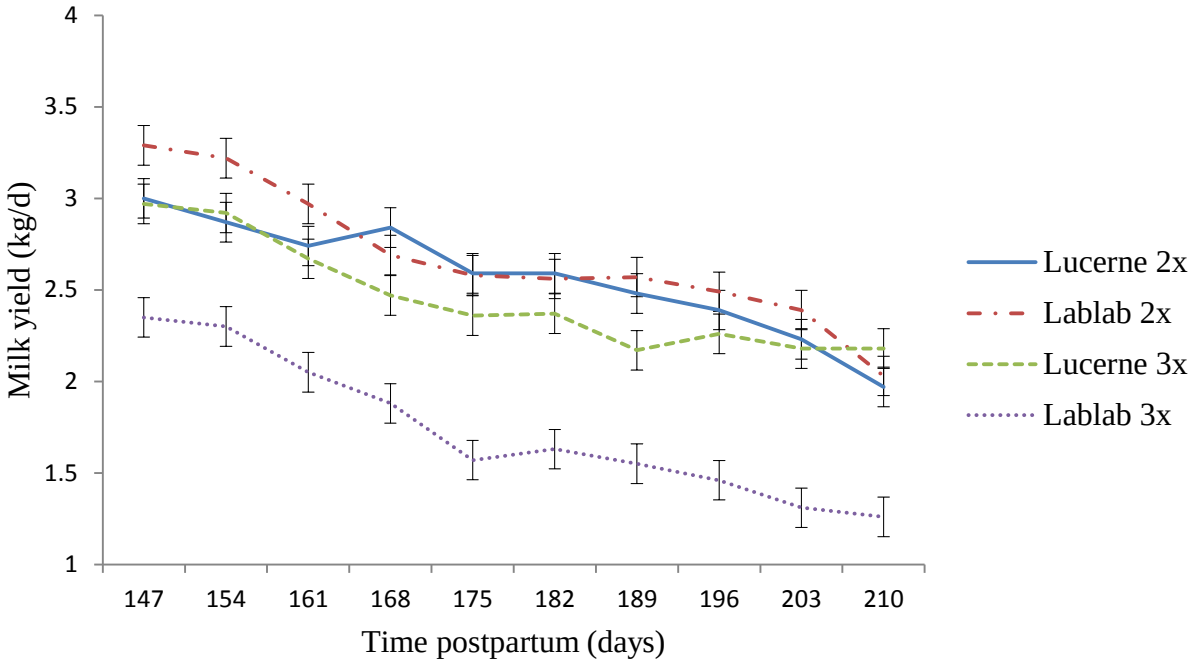

Figure 4.3: The average milk yield (kg/d) of mid-lactating Saanen dairy goats managed under intensive management system and being fed Lucerne or Lablab and milked 2x and 3x a day during 147-210 days postpartum.

Survey Questionnaire for Study one

I am an MSc student (Animal Science) at Botswana College of Agriculture. In collaboration with the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), we kindly ask for your assistance in conducting a survey on the current status of dairy goats in Botswana by answering this questionnaire. Your confidentiality is highly secure since your identity will not be revealed.

The current status of dairy goat's milk production in Botswana: Constraints and Opportunities.

Name of interviewer: Mr. Kealeboga Dipheko

(Tick the appropriate number in the box where applicable)

Section A: Demographic characteristics

i. Village: _____

ii. District: _____

iii. Gender: ❒ male❒ Female

iv. What age group are you?

1. Below 35	**2. 36-50**	**3. 51-60**	**4. Over 60**

v. Marital Status: 1❒Single 2❒Married 3❒Divorced 4❒Widowed

Section B: Socio-economic status

I. What is the highest level of education you have attained?

1 None	2 Can read and write	3 Primary School	4 Secondary School	Tertiary School

II. Employment type

1 None	2 Formal	3 Informal	4 Others (specify)

III. What are your other sources of income?

1 Selling live goats	2 Arable farming	3 Others (specify)

Section C: Ownership of goats

I. When did you start keeping goats? ……

II. Where did you get financial support to buy your goats?

1. FAP	6. Salary (monthly income)
2. CEDA	7. Pension
3. NDB	8. inheritance
4. Youth Grant	9. Poverty eradication programme
5. LIMID	10. Others (specify)

III. How many dairy goats do you have?

Class	**Females**	**Bucks**	**Castrates**	**Kids**
Number				

IV. What other livestock do you keep and how many of each?

Species	cattle	Sheep	Pigs	Poultry	Goats	Dairy goats	Others
Number							

Section D: Management

I. Housing

i. Do you provide shelter for your goats?❒ Yes ❒ No

ii. If yes, indicate the type of material used to provide shelter for your goats

1 Tree branches	2 Traditional poles + fence	3 Gum poles + fence	4 Others (specify)

II. What breeds of goats do you keep?

Breed	Saanen	British Alpine	Toggenburg	Crosses
Number				

ii. Do you milk your goats? ❒ Yes ❒ No

iii. If yes, how many times did you milk them per day? ❒ Once ❒ Two times ❒ Three times

iv. How much milk is the highest goat producing at peak of lactation? ……....

v. How much milk is the lowest goat producing at peak of lactation? **.....**

vi. What is the total milk produced from goats per day? ……

III. Nutrition

i. What kind of feeds do you provide to your goats?

1 Pasture	2 Fodder	3 Both pasture + fodder	4 Others (specify)

ii. Do you provide any supplementary feeds to the goats you milk? ❒. Yes ❒ No

iii. If any supplementary feeding is given, please specify the type

……

iv. If No, give reasons for not supplementing

……

IV. Health

i. Do you experience any losses of your goats? ❒. Yes ❒ No

ii. Which breed is prone to the losses? ……

iii. What do you do to control/treat/prevent the disease(s)?

_____

iv. Do you have access to veterinary and/or extension services? ❒. Yes ❒ No

v. If yes, how frequent do veterinary or extension assistants visit your farm?

Rarely	Often	At times
1	2	3

5 Have you ever attended any training on dairy goat production? ❒. Yes ❒ No

i. If yes, did you find training useful? ❒. Yes ❒ No

ii. If no, would you like to attend any training on dairy goat production? ❒. Yes ❒ No

iii. Do you keep records of your goats? ❒. Yes ❒ No

iv. If yes, what benefits do you realize from record keeping?

Monitor profit and losses	To see if production is declining	Identify sick animals	Others (specify)
1	2	3	4

I. Marketing

i. Do you sell goat milk? ❒. Yes ❒ No

ii. If yes, how often do you sell milk?

Rarely	Often	At times
1	2	3

iii. In what form do you sell the milk?

…….....

iv. What are the reasons for selling the milk?

In need of cash	Profits are high	Others (specify)
1	2	3

v. Is the market for goat milk satisfactory? ❒. Yes ❒ No

vi. Who are the main buyers of your goat milk?

Individual	Retailers	Organizations	Others (specify)
1	2	3	4

vii. How long have you been selling milk from your goats? _____

viii. Do you sell male goats? ❒ Yes ❒ No

ix. If yes, at what age are you selling them? …….

x. What is the average price for selling your male goats? ……

xi. What are your customers for your male goats? ……

xii. Do you sell female goats? ❒ Yes ❒ No

xiii. If yes, at what age are you selling them? …….

xiv. What is the average price for selling your female goats? …….

xv. What are the reasons for selling your female goats?

……

xvi. What do you do with the money from the sale of your goats?

……

xviii. What problems have you experienced from keeping dairy goats on your farm?

Categories	Tick only the one that affects you
Animal husbandry and management	1. mortality due to:
	2. Environment (acclimatization)
	3. Parasites (specify)
	4. Diseases (specify)
	5. Theft
	6. Predation, specify
	7. Drought
Resources	8. inadequate feeds due to:
	9. low rainfall
	10. Low quality available feeds
	11. Insufficient supplements in the area
	12. Insufficient grazing and production land
	13. Insufficient veterinary requisites
	14. Lack of finance
	15. Insufficient labour
	12. Lack of formal market
	13. Lack of milking equipment and infrastructure
	14. Lack of knowledge about dairy goats production
Production	15. Availability of the breeding stock
Others (specify)	

xvii. What opportunities do you realize in keeping dairy goats and milk them in future?

_____