

**Effects of goat phenotype score on milk
characteristics and blood parameters of
indigenous and improved dairy goats in South**

by

Roger Gollah Pambu

B.V.M. (UniLu), B. Inst. Agrar (Hons), MSc (Agric) Anim. Sci. (UP)

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DECLARATION

I declare that this thesis for the PhD (Animal Science) degree at the University of Pretoria has not been submitted by me for a degree at any other university

Signed: 01 October 2011

Roger Gollah Pambu

SUPERVISOR: Prof. Edward C. Webb

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Our special prayer to The Almighty God in whom we have entrusted our hope, our faith and our love in his capacity of father, of provider and of protector; He who has, today, made his glory shines upon the orphan that I am; the lonely orphan I have always been.

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ABSTRACT

The aim of this study was to develop and examine the validity of using a phenotype scoring system (PTS), a new concept, in evaluating milk yield and constituents in different goat genotypes (Indigenous, British Alpines, Saanen and Toggenburg) raised in small scale production systems. Strategic decisions of small scale African farmers are mostly based on visual appraisal or body condition scoring (BCS) of their animals. BCS has been highly recommended as a means to evaluate both the energy and the health status of animals, especially in beef farming, but this method has been criticized for being too simple and too subjective because its evaluation is often done too late after the damage has already happened. Phenotype scoring (an approach which includes breed, udder size and BCS of the animal) is presented in this study as a better tool to evaluate milk yield in different goat genotypes raised under free range conditions. This has also been a good opportunity firstly to indicate which, among the three dairy breeds of goat under discussion, can adapt best to the African small scale farming system; secondly to review the relevance of some blood metabolites in characterizing milk production in different goat breeds and thirdly to study the milking capacity of the indigenous compared to the dairy goats raised under small scale production systems in South Africa.

Thirty-two goats (8 Indigenous, 8 British Alpines, 8 Saanen and 8 Toggenburg) were raised in a free range system at the ARC-Irene experimental farm close to Pretoria. The experiment was a completely randomized experimental design with eight replicates per treatment group. Blood samples were collected by jugular venipuncture into 10 ml heparinised tubes in the morning before feeding on a weekly basis over a period of two months. Blood plasma was immediately aspirated after centrifugation (3000G), kept on ice and brought to the laboratory for the analysis of glucose, cholesterol, urea nitrogen (BUN) and free fatty acid (FFA) concentrations.

Immediately after, all does were entirely milked (followed by 1ml oxytocin IM injection and the kids taken away for a period of four hours) before a second milking session took place to measure the daily milk yield of the does. Milk samples were analyzed for lactose, milk proteins, milk fat, milk urea-nitrogen (MUN) and milk

somatic cell count (SCC). In addition body condition score (BCS), age and data related to the goat genotype (breed, udder characteristics) were recorded.

Results confirmed that milk yield from dairy goats was higher ($p < 0.001$) than the milk yield of indigenous goats during the entire period of study. Milk lactose values recorded in this study (between 3.9 and 4.9%) were the most stable constituent in goat's milk. Milk protein concentration (between 3.1 and 4.5%) was significantly higher in the indigenous than in dairy breeds, especially in week one and from week four onwards. Milk fat values (between 3.3 and 7.7%) displayed a decline in all breeds; but as from week three, the fat in milk of indigenous does increased and from week five onwards, it remained significantly higher ($p < 0.001$) compared to that of dairy breeds. In conclusion, the superiority of dairy breeds in milk yield was proven while the quality of indigenous goat milk was recognized.

Studies on the characterization of milk production in different breeds revealed that the Toggenburg was superior to the other breeds, followed by the British Alpines and the Saanen; but the British Alpines showed a better adaptability to the environment followed by the Toggenburg and the Saanen. The latter could not produce milk without feed supplementation and lost most body condition as compared to the other breeds.

Statistical analyses indicated that breed influenced milk yield, milk fat and the protein content of milk (especially in the Saanen and Toggenburg goats). BCS influenced fat content, lactose, milk proteins, MUN and SCC and also milk yield. Udder size influenced milk proteins and milk yield while udder attachment was associated with milk yield only.

These results show that PTS, because it takes into account BCS, breed and udder size, is a better tool for predicting milk yield of goats herded in small scale farming systems. Africans interested in dairy goat farming should adopt PTS as a means to evaluate milk yield especially since milk is sold per volume and not by quality in Africa.

Finally, milk from the indigenous goats is superior in terms of lactose, fat and protein content. The latter quality attributes can be used as selection criteria since the milk industry pays premiums for the fat and protein content of milk.

SUMMARY

In Africa, the Indigenous goats are the most expanded breed of goat found in rural areas. This breed is generally raised under unfavourable environmental conditions which have largely contributed to promote a poor public image associated to goats. In South Africa more especially, several milk goat breeds (Saanen, Toggenburg and British Alpines) are also raised at present. In general the African goat farmers do not know exactly what to do with their goats which are left on their own, thriving and scavenging as much as they can in the backyard.

In Chapter 1 of this study, the aim, objectives, motivation, hypotheses and research questions have been outlined.

In general, literature on goat milk constituents is scanty; just as it is on the blood metabolites involved in goat milk production; Chapter 2 is, in essence a summary of the relevant literature and a short review on the PTS.

The research methodology used in this study was a simulation of the way goats are raised in the small scale farming system of tropical Africa. Details on the materials and methods used are described in Chapter 3.

In this study, dairy breeds produced quantitatively more milk than the indigenous does, while milk from the indigenous does was of better quality. Results are presented in Chapter 4.

In Chapter 5, results on the blood metabolites involved in milk production are presented separately; but as recommended by Rowlands (1980), they are discussed in conjunction with the other blood metabolites implicated in the specific physiological process involved.

The correlations between the phenotypic characteristics and firstly, the milk constituents and secondly, the blood parameters, are explained in Chapter 6.

A general conclusion is drawn in Chapter 7 while the list of references, the bibliographic material as well as the addendum of the raw data used in this study are available at the end of the thesis.



LIST OF ACRONYMS

AA	Amino acids
AI	Artificial insemination
BA	British Alpines
BCS	Body condition scor (e) (-ing)
BUN	Blood urea nitrogen
CP	Crude protein
CHO	Cholesterol
D	Dairy
DM	Dry matter
FA	Fatty acids
FFA	Free fatty acids
GLU	Glucose
IND	Indigenous
IM	Intramuscular (injection)
IR	Infrared
LAC	Lactose
MCT	Medium-chain triacylglycerols
MFA	Milk fatty acids
MUN	Milk urea nitrogen
MY	Milk yield
EFA	Non-esterified fatty acids
NBR	Number
NPN	Non-protein nitrogen
PMO	Pasteurized milk ordinance
PROT	Protein
PUFA	Poly-unsaturated fatty acids
PTS	Phenotype scoring system
RDP	Rumen degradable Proteins
RUP	Rumen un-degradable Proteins



SCC	Somatic cell count
SC	Subcutaneous (injection)
SNN	Saanen
SUP	supplement
TOG	Toggenburg
Uat	Udder attachment
UDP-Galactose	Uridine-DiPhosphate Galactose
Usz	Udder size
USA	United States of America
VFA	Volatile fatty acids
vs	Versus

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CHAPTER 1

Introduction

1.1 Project theme

Goat milk production

1.2 Project title

Effects of goat phenotype score on milk characteristics and blood parameters of indigenous and improved dairy goats in South Africa.

1.3 Motivation

In Africa, interest in goat (*Capra aegagrus hircus*) farming has increased considerably in the last 10 years in Africa. For example, in Kenya, more than 3000 smallholders are now involved in goat farming and the population of crossbred dairy goats has increased from less than 20,000 in 1991 to over 260,000 in 2004 (Ahuya *et al.*, 2009). In Tanzania, there is a rapid increase of dairy goats especially among the resource poor smallholder farmers where these animals contribute substantially to supply milk for children and women. Tanzanian family incomes and nutrition have appreciably improved in areas where dairy goats have been introduced (Kifaro *et al.*, 2009). In Nigeria, caprine milk appears to be more ideal for farmers interested in butter production (Malau-Aduli *et al.*, 2002). In Gambia, apart from ceremonial purposes milk for home consumption cannot be ignored (Jaitner *et al.*, 2006). In South Africa, meat breeds such as the South African Boer and Indigenous goats are milked for household consumption (Casey and Van Niekerk, 1988).

Qualities mostly associated with goats include: feed efficiency for meat and milk production, low maintenance cost, robustness and great adaptation to the harsh environmental conditions as well as the inherent suitability for small-scale production systems (Mengistu, 2007). Goats are also a safe investment as compared to crop products usually subjected to seasonal variables like drought, floods, veld fire, acid rains, and acarid attacks. Being a browser, goats (which have the advantage of producing larger

volume of milk than cattle which are grazers) is a much more manageable animal than cows (Berry *et al.*, 2002; Richardson, 2009).

Given the relatively lower cost of production characterizing goat farming, more farmers may engage in the milking goat as a possible farming alternative. However, limited information pertaining to nutrient requirements of various breeds of goat in Africa presents a challenge to dairy goat farming. The main challenges are:

- i) Selecting an appropriate breed or crossbreed to utilize for milk production
- ii) Determining nutritional requirements of the lactating dairy goats
- iii) Visual appraisal methods or tools to determine the goat milking potentials.

Visual appraisal or Body Condition Scoring (BCS) has been recommended by many authors (Russell, 1983; Nix, 2004; Caldeira *et al.*, 2007 and Villaquiran *et al.*, 2007) as an appropriate routine practice in goat farming for the assessment of body energy reserves. Some other authors however (Hady *et al.*, 1994; Halachmi *et al.*, 2008; Garcia *et al.*, 2008; Rumoza Gwaze *et al.*, 2010) have criticized BCS as being subjective, too simple and without accuracy. As apparent, BCS may not be an appropriate tool for the assessment of the goat milking potential. Another indicator needed to be created whereby several factors would be assessed and mathematical relationships developed. Since the factors envisaged for this relationship/assessment included BCS, breed, udder characteristics and age, an empirical term of “phenotype score” was proposed. The focus was the possible use of the “phenotype score” (rather than the BCS alone) as a milk yield predictor. Accuracy in predicting milk yield is critical and hence more appropriate tools needed to be incorporated in the new scoring system. Milk yield and constituents being isotonic to some blood metabolites implied that these blood parameters be incorporated into the evaluation exercise. A study on the interactions between milk characteristics and blood metabolites needed to be done. The purpose was to create and evaluate the “phenotype scoring system” (PTS) as a milk yield predictor.

1.4 Statement of the problem

The continuous and rapid increase of goat populations points to the possibility that these animals might assist in solving some challenges (poverty, joblessness, famines, under/mal nourishment) currently affecting Africa. There are however, some constraints to the development of goat farming, consumption of goat milk and/or production of milk products in Africa. The major constraints are i) the paucity of scientific information on goat reproduction to help improve goat herd management (Amoah,1995) ii) the unfamiliarity of goat milk and goat milk products (Silanikove *et al.*, 2008) and iii) the lack of public knowledge of, and appreciation for, the indigenous goat's unique qualities (Devendra, 1980). In Africa, the indigenous goats generally have a poor public image. They are even called “the poor man’s cow” (Omondi *et al.*, 2008) and often regarded as “backyard animals” of little commercial significance (De Vries, 2008).

There is a need for the African scientists to develop some technical tools that will inform the goat farmers on how to fine-tune decisions in response to the feeding requirements, the productive and reproductive physiology of their herd. Here again, the “Phenotype scoring system” (PTS), which is based on the study of i) milk ii) its constituents iii) the associated blood metabolites and iv) the interactions between milk, blood and the phenotype characteristics, is expected to provide valuable information to farmers and goat keepers. Knowledge concerning goat nutrition, productive and reproductive physiology is critical in improving dairy goat farming in Africa.

1.5 Aims

The aims of this research were to develop and evaluate firstly the “phenotype scoring system” (a new concept which encompasses BCS, breeds, udder characteristics and age) as a tool for predicting goat milk characteristics; secondly, to evaluate the variation in milk yield and constituents between Indigenous and dairy breeds of goat and thirdly, to determine which one(s) of the currently raised breeds of dairy goats in South Africa can suit to the small scale farming system.

1.6 Objectives

The overall objectives of this study were:

- i) To assess the phenotype scoring system (PTS) as a predictor of milk yield and constituents in the Indigenous and the dairy breeds of goat.
- ii) To evaluate the suitability (adaptability) of different breeds of goat to the tropical environment, as reflected by the relationship between their phenotype characteristics and some blood metabolites (glucose, blood urea nitrogen, free fatty acids, cholesterol).
- iii) To compare milk yield and constituents (lactose, milk protein, milk urea nitrogen and milk fat) of the Indigenous to the dairy does.

1.7 Hypotheses

- i) Ho: PTS is a good predictor of milk yield and composition in goats.
- ii) Ho: The Indigenous goat is the best suited to the tropical environment
- iii) a) Ho: Dairy goats yield more milk than the Indigenous breed.
b) Ho: The Indigenous milk is higher in lactose, milk fat, milk protein and milk urea nitrogen than milk of dairy does.

1.8 Research questions

In view of the hypotheses referred to above the research questions were

- i) Can PTS be useful in predicting milk yield and constituents in both the indigenous and the dairy breeds of goat in small scale farming systems?
- ii) Which breed of goat raised in South Africa adapts most efficiently to the prevailing African environmental constraints? How will these breeds perform (milk production and BCS) if they were to be raised under the current African small scale farming systems.
- iii) Can the indigenous goat milk structure make any contribution as a potential developmental asset in African rural areas?

CHAPTER 2

Critical review of lactation and factors affecting lactation in domesticated goats

2.1. General introduction

The goat world population is estimated at 746 million (FAOSTAT 2010) of which 223 millions are raised in Sub-Saharan Africa with the majority (more than 90%) being raised by smallholder farmers (Rumoza Gwaze *et al.*, 2010). In South Africa approximately 7 million goats are raised (Donkin and Ramsay, 2000); and out of nine provinces, three use goats for milk production. Goats are available to Africans, who therefore have the potential to produce their own milk in abundance (quantity and quality).

Domestic goats (*Capra aegagrus hircus*) belong to the kingdom of *animalia*, class of *mammalia*, order of *ruminantia*; family of *bovidae*. The modern goat is a subspecies of goat domesticated from the wild goat of southwest Asia and Eastern Europe between 7000 and 6000BC; it is closely related to sheep; both of them belong to the antelope subfamily of *caprinae*. (Goat-wikipedia) For thousands of years, goats have been used for milk, meat, mohair and skins production over much of the world (Mamabolo, 1998). Female goats are referred to as *does* or *nannies*; intact males as *bucks* or *billies*; their offspring are *kids*. The name “*kid*” also refers to goat meat from younger goats while the term “*chevon*” refers to meat from older goats. As a member of the *bovidae* family the goat has the ability to convert plant carbohydrates and proteins into available nutrients for human use: milk. Goats can be incorporated into a crop rotation to take advantage of nutrient cycling; they can also be used to control weeds, to harvest crop residues or fight bush encroachment (Goat-wikipedia).

Goats belong to the order of “*ruminantia*”, which means that they are members of the group of animals equipped with a “rumen” (the first major compartment of the four-compartment stomach that characterises the cow, the sheep and the goat). The rumen is the “furnace” chamber where microbial fermentation takes place thanks to the millions of

bacteria, protozoa and fungi that inhabit the rumen. These ruminal microbes have the capacity to use the energy-rich plant parts, making them digestible for the host animal. Most of the grasslands and rangeland plants harvested by the ruminants are made of cellulose (the portion of the plant structure that comprises the walls of the plant's cells). Cellulose is very fibrous and indigestible to monogastrics (simple stomached animals). But rumen microbes do produce an enzyme called “*cellulase*” which is the only mammalian secretion capable to breakdown cellulose into cellobiose and then to glucose which is digestible to the microbes and subsequently to the host animals (Rinehart, 2008). Digestion begins when an animal takes a bite from the pasture; as the animal chews, the feed is formed into “bolus” (a packet of food capable of being swallowed). Saliva is excreted, which further aids in swallowing and serves as a pH buffer in the stomach. Once in the rumen, the feed begins to undergo fermentation. Rumen microbes ingest the feed, turning out the end-products which serve as a major source of nutrients for the animal. Some of the principle products formed are ammonia (NH₃) methane (CH₄) carbon dioxide (CO₂) and the volatile fatty acids (VFAs) namely acetate, propionate and butyrate (Church, 1979; Perry, 1980).

Of the three VFAs, acetate is found in large extent circulating in the peripheral blood; in the lactating ruminant. The mammary gland is an important user of acetate for milk fat synthesis. As with acetate, propionate is largely unaltered by the rumen epithelium; it (propionate) is transported via the hepatic portal vein to the liver where it serves as a primary precursor for glucose synthesis which is also synthesized at a lesser contribution from AA, lactate and glycerol. Butyrate, which is found in much smaller quantities than acetate and propionate, is extensively metabolized within the rumen and omasum epithelial cells to form aceto-acetate and beta-hydroxy butyrate; any butyrate reaching the peripheral circulation is either oxidized or contributes to fatty acid synthesis (Sherwood *et al.*, 2005). The other end-products resulting from the microbial activity are the large quantities of gas produced – mainly methane (CH₄) and carbon dioxide (CO₂), which must be expelled from the animal through the processes of respiration and eructation on a continuous basis otherwise bloating, ending in death, can occur quickly (NRC, 2007) .

Ruminants require two types of protein in their diet, the protein degraded in the rumen or also the “rumen degradable proteins” (RDP) which are essentially food for rumen bacteria (when microbes die they are passed through to the stomach to the small intestines where they are digested by the animal and absorbed into the animal’s bloodstream). The second group of proteins required by the ruminants in the diet is the one that does not undergo rumen degradation, but passes straight to the abomasum or stomach for digestion; this group of proteins is referred to as “rumen undegradable proteins” (RUP). This is the group of proteins that does benefit directly to the animal body. Rumen microbes differ in preferences for nitrogen sources, with ammonia being the most preferred source of many bacteria. Ammonia is absorbed into the animal’s system through the rumen wall or is consumed by bacteria to become microbial protein. The microbial protein is then passed through the digestive system to be absorbed in the small intestines (Sherwood *et al.*, 2005)

Energy is the single most important dietary component for an animal after water; energy is derived from carbohydrates, fats, proteins and from the animal’s body reserves. Energy intake maintains body functions and facilitates growth and development, including reproduction and lactation (Rinehart, 2008).

2.2 Goat milk yield and constituents and some blood metabolites associated with milk production.

2.2.1 Goat milk yield

Goat milk is popular in the nutrition of babies allergic to cow milk and for various therapeutic uses, including the production of up-market cheeses and powdered milk (Silanikove *et al.*, 2008). Milk is the liquid nutrient secreted from the mammary gland of mammals for their young (Sherwood *et al.*, 2005). It has also been defined as the normal clean and fresh secretion from the mammary epithelial cells of a healthy female mammal excluding week one pre- and post-partum (Pulina, 2002). Milk is secreted from the mammary gland which consists of glandular tissue made of mammary epithelial cells that produce milk and of the excretory ducts that take milk out of the organ. The mammary epithelial cells surround a spherical lumen called milk alveolus; when the cells surrounding the alveoli contract, the hydrostatic pressure in the alveolar lumen increases

and milk is propelled out of the alveoli into milk ducts that empty themselves in a wider chamber called the cistern where milk will be stored before and between lactation ((Sherwood *et al.*, 2005).

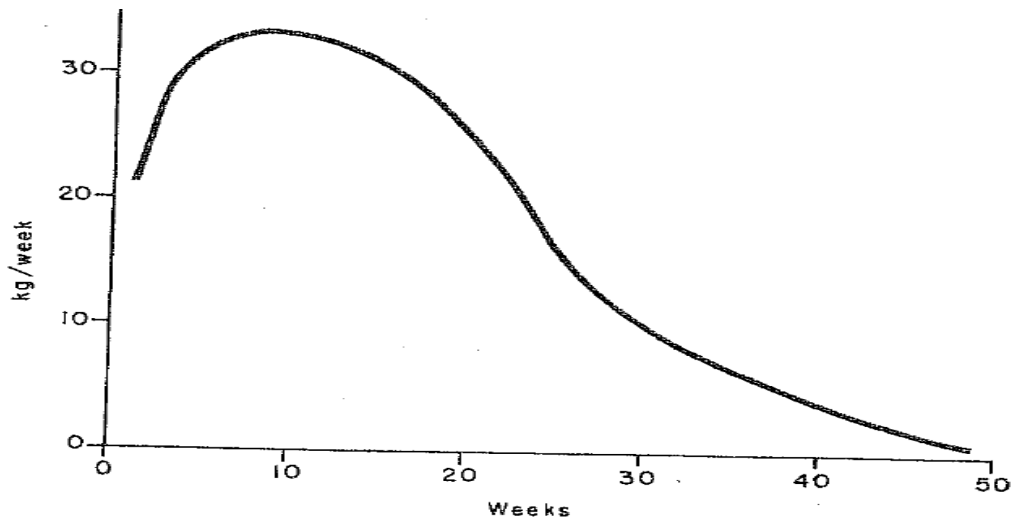
Presumably, the role of hormones is primarily to induce and maintain the activity of synthesizing enzymes in the cells. The rate of uptake of glucose and AA is determined by the rate of synthesis in the mammary epithelial cells, and not by changes in the plasma concentration of metabolic hormones such as insulin, glucagon and growth hormone, which regulate the rate of uptake of these substrates in many other tissues. The mammary cells can take up to 25% of the glucose and up to 60% of the AA that are provided in the blood (Sherwood *et al.*, 2005). Uptake of glucose and AA by the udder is given priority and the udder is allowed to benefit from energy sources stored in other tissues such as adipose and muscle tissues. In dairy cows use of body tissue energy for milk production can account to 82 % (Moe, 1981). Such a redirection of the utilization of nutrients in the body is called “homeorhesis” which is under hormone regulation (Baumann *et al.*, 1983; Bell, 1995)

Under homeorhetic regulation lactation uptake of glucose by the mammary gland increases considerably while uptake and utilization of glucose in muscles and adipose tissue is reduced. If insufficient amounts of AA are absorbed from the intestinal tract, muscle proteins will be broken down into AA to be utilized by the mammary epithelial cells. These changes in nutrient partitioning between organs during lactation will occur even when the concentrations of many nutrients in the blood are within the same range as in non-lactating animals (Sherwood *et al.*, 2005).

Earlier studies conducted by Sahlu *et al.* (2007) investigated the effect of diets in milk production and constituents on 249 pastured dairy goats; results showed that milk production and composition were affected by feeding treatment and year. In South Africa, Greyling *et al.* (2004) compared milk production potential of indigenous and Boer goats fed two different feeding systems. It was seen in the intensively maintained groups that feed intake was significantly ($P < 0, 01$) correlated to milk production irrespective of the breed. Raats (1988), who worked on the effect of supplementation on milk yield in Boer goats and found that milk production is affected by level of nutrition, reported similar results. However, reports on the effect of level of nutrition on milk constituents

are sometimes contradictory. Oltner *et al.* (1983) found slight changes in yield according to level of nutrition and protein/energy ratio, but no obvious patterns emerged.

To conclude, milk yield is subject to much variation i) both between and within breeds (Makun *et al.*, 2008; Richardson, 2009) ii) with age, stage of lactation, parity and season (Pulina, 2002). A classic lactation curve of does reported by French (1970) is represented in Graph 1.1.



Graph 1.1: Lactation curve of does during one year (French, 1970).

2.2.2. Goat milk constituents

Milk constituents are principally synthesized by the secretory cells of the mammary gland from the precursors adsorbed from blood circulation. These precursors derive directly or indirectly from nutrients in the diets (Pulina, 2002). Goat milk can successfully replace cow milk, especially for people who are allergic to cow milk; it is nearest to human milk in its content of fat and protein (see Table 1.1 and Table 1.2, next page) and serves as a good dietary source of minerals which makes it a complete food for neonates (Bawala *et al.*, 2006). Goat milk is a very tasty, very delicious and very nutritious product with a slightly sweet and sometimes salty undertone.

Table 1.1: Average composition of milk from different mammals by percentage

Species	Water	Fat	Proteins	Lactose
Goat	87.00	4.25	3.52	4.27
Cow	87.20	3.70	3.50	4.90
Ewe	80.71	7.90	4.81	4.81
Human	87.43	3.75	1.63	6.98

(Source: Webb and Johnson, 1965)

Table 1.2: Average vitamin content of goat, cow and human milk

Vitamins	Cow	Goat	Human
A	1560.0	2074.0	1898.0
D	---	23.7	22.0
B1	0.44	0.40	0.16
B2	1.75	1.84	0.36
Nicotinic acid	0.94	1.87	1.47
B12	0.0043	0.0006	0.0003
C	21.1	15.0	43.0

(Source: Prakash and Jenness, 1968)

Cow's milk is the most commonly used by humans, but goats milk is more valuable than cow's milk in terms of DM (dry matter), milk fat, milk proteins, lactose or even minerals like Ca, P, Cu, Mn, and K or vitamins like Vit. B₃ and Vit. A (Pruzs and Selegovska, 2004). Goat milk is richer in vitamins and minerals; as such, it is particularly appropriate for the diet of elderly, the sick and the children (Dario *et al.*, 2008). Goat milk is more digestible than cow's milk, because of its protein make-up: its low levels of the protein α s1-casein – which is responsible for allergy to certain persons – than cow's milk. Some goats do even naturally produce very little α s1-casein. Goat milk can be drunk fresh; pasteurization is however, recommended to reduce naturally occurring bacteria such as *staphylococcus aureus* and *eischerichia coli* (Clark, 2007)

The gross biochemical composition of goat milk varies markedly with different breeds, physiological and environmental factors; however, the composition below (Sherwood *et al.*, 2005) is generally accepted as a standard:

- Carbohydrates (lactose) 4.5%
- Milk Fat 4.1%
- Proteins 3.6%
- Calories (kcal) 69 %
- Minerals 0,7% and
- Water 87%.

Lactose, milk fat, milk proteins and water are the main components of milk.

2.2.2.1 Lactose content of goat milk

Lactose is the milk sugar or the carbohydrate nutrient in milk (Richardson, 2009). Lactose is synthesized from glucose extracted from blood by lactose synthetase enzyme activity of the Golgi apparatus in the mammary gland's epithelial cells. Lactose, a non-permeable disaccharide which consists of two molecules (one glucose and one galactose) connected by a β -1-4 glycoside bond is too large to diffuse out of the Golgi apparatus or out of the secretory vesicles; so it draws water by osmosis into the Golgi from the cytoplasm (Zubay, 1986). When milk synthesis starts, the mammary epithelial cells under the influence of prolactin induces the synthesis of α -lactalbumin which then binds to the regulatory unit of lactose synthetase which in turn will link UDP-galactose to glucose, forming lactose; between 50 and 60 % of the glucose taken up from plasma is used to form lactose (Sherwood *et al.*, 2005).

Lactating ruminants often exhibit a glucose deficiency when milk production is high, because the udder then uses between 70 and 80% of the total available glucose. Bauman *et al.* (1980), Bergman (1983) and Weekes (1991) indicated that 85 to 90% of the total glucose produced in the ruminant was taken up for lactose synthesis during lactation; a finding later supported by Chang *et al.* (1996) who showed that the uptake of glucose by the mammary gland of the dairy goat amounted to 14.6 mg/dl of the blood perfusing the udder. In earlier studies Hossaini-hilali *et al.* (1993) investigated fluid

balance secretion in fed and feed-deprived black Moroccan goats; results showed that plasma glucose concentration was higher in lactating than in non-lactating goats; this was later verified by Pambu (1997) who worked on Indigenous goats in South Africa and found a difference in blood glucose concentrations between the lactating and non-lactating goats. This was also the opinion of Hussain *et al.* (1996) who compared the underfed goats to the well fed group and explained that, during lactation, there was an increased glucose requirement for lactose synthesis; a finding earlier supported by Radloff *et al.* (1966) who reported a positive correlation between blood glucose concentration and lactose and also milk protein concentrations.

Many authors (Faulkner *et al.*, 1979; Sano *et al.*, 1985 and Bell, 1995) have mentioned that blood glucose is the only precursor of milk lactose and therefore, glucose uptake by the udder is important for milk secretion. It has been indeed demonstrated that anything that alters blood glucose concentration: cold stress (Faulkner *et al.*, 1979), heat stress (Sano *et al.*, 1985), administration of insulin and intra-ruminal infusion of acetate (Rook *et al.*, 1966) does also affect lactose and, as a consequence, milk yield. Glucose is definitely the only precursor to lactose synthesis and lactose is the most important osmotic solute in milk (Bell, 1995). Pulina (2002) expressed this view by saying that milk is osmotic with blood plasma while lactose is the main osmolar component of milk.

In short, lactose importance in determining milk volume is such that, if, secretion of lactose ceases, milk volume will be greatly reduced (Pulina, 2002). Glucose plays an important role in the secretion of milk (approximately 85% of the lactose is synthesized from glucose); if plasma concentration of glucose falls below a certain level, lactose secretion will cease; and milk secretion will be impaired; for this reason lactose may stand as an indirect indicator of the energy status (Bed *et al.*, 2007). Lactose concentration is relatively constant (4.8% on average) in milk; lactose and triglycerides are primarily utilized as energy sources (Sherwood *et al.*, 2005).

2.2.2.2. Protein content of goat milk

Milk proteins with the exception of serum albumin and immuno-globulins are synthesized from the amino acids (AA) extracted from blood in the rough of endoplasmic reticulum of the epithelial cells and are transported to the Golgi apparatus where some are

modified before they are transferred to the secretory cells. Those AA derive from the post-ruminal digestion of microbial protein and the undegradable rumen protein (RUP) from hepatic transamination reactions, and when ration protein concentration is scarce, from the mobilization of tissue proteins (Pulina, 2002). Goat milk contains a similar AA profile to cow milk except for a lower concentration of cysteine and a higher concentration in taurine; glycine and glutamic acids are the major goat milk free AA. Taurine more specifically is involved in bile salt formation; it regulates blood pressure and alleviates other cardio-vascular ailments in adults (Silanikove, 2008). Milk proteins composition from the lowest to the highest electrophoretic mobility is:

- α -casein, β -casein, K-casein, γ 1-casein, β -lactoglobulin, α -lactalbumin, γ 2-casein and γ 3-casein)
- Minor whey proteins (Lactoferrin, Serum albumin, Immunoglobulin G) (Albenzio *et al.*, 2009).

Although the principal proteins in goat milk are the same as in milk from other species, the relative proportion of the four major caseins in caprine milk varies widely between individual animals (Albenzio *et al.*, 2009). Serum albumin and immunoglobulins, which are very high in colostrum and increase during mammary gland inflammation and during uterus involution, are not synthesized in the mammary gland; they pass directly from blood into milk ((Sherwood *et al.*, 2005). The lactating mammary gland of goats has the ability to utilize AA of peptide origin for milk synthesis (Backwell *et al.*, 1994). Removal of AA supply for milk synthesis at the level of the mammary gland is a function of AA supply (concentration and blood flow) and the affinity of the udder for individual AA. Blood flow and AA transport activity appear to act in concert to allow the udder to cope with fluctuations in AA concentration and to ensure that the uptake of AA is adequate to meet the demands for milk proteins synthesis (Mabjeesh *et al.*, 2002).

The composition of total protein in milk depends on the energy/protein ratio in the diet, on its crude protein concentration and on the use of the rumen-protected protein (Pulina, 2002); during early lactation the ability of the animal to produce milk frequently exceeds her ability to consume sufficient energy to meet requirement for milk production. The animal must rely heavily on body stores of energy and protein during this period; this

breakdown of muscle proteins to provide AA for milk protein is a mechanism of normal metabolic adaptation (Boots *et al.*, 1978). Milk protein is therefore positively correlated to the energy content of the ration, particularly when the additional energy comes from soluble carbohydrates.

Generally dietary crude protein (CP) concentration affects milk yield and consequently results in protein yield increases. The reverse is also true, when animals are fed poor quality forage (or a diet deficient in CP), milk proteins content decreases. A negative relationship between dietary CP and milk proteins percentage can also be an indicator of excess RUP in diets. Excessive RUP has been associated with decreases in microbial protein synthesis and AA flow to the small intestine. On the other hand, feeding excessive degradable CP, such as urea, can reduce milk proteins content. To optimize the dietary utilization of nitrogen, the diet should be balanced for energy and protein both for quantity and for rumen kinetics (Sherwood *et al.*, 2005).

2.2.2.3 Lipid content of goat milk

One of the most interesting aspects of milk from small ruminants concerns the nature of its fat. The higher proportion of small milk fat globules present in goat milk as compared to cow milk does contribute to the tendency of goat milk to be more easily digested (Silanikove, 2008). Cow milk fat globules tend to separate to surface; in contrast, goat milk globules are much smaller and remain suspended in solution, thereby reducing the need for homogenization (Clark, 2007). Milk from sheep and goats has a fat rich in medium-chain triglycerides (MCT) made up of fatty acids (FA) with a carbon chain composed of 6 to 10 atoms of carbon; these are caproic (C6:0), caprylic (C8:0) and capric (C10:0) fatty acids, also called “goat fatty acids” (Sanz-Sampelayo *et al.*, 2006) of which capric (C10:0) fatty acid in particular is responsible for the characteristic goaty odour of goat milk and is therefore useful to distinguish goat’s milk with different FFA composition (Pereira *et al.*, 2008).

The so called “Goat fatty acids” are bound to glycerol and together they make up to one-fourth to one-fifth of all the FA found in the goat milk (Astrup *et al.*, 1985). Milk fat is composed primarily of microscopic membrane-covered droplets of triglycerides, which are formed by the linking of glycerol and fatty acids synthesized at

the outer surface of the smooth endoplasmic reticulum. The major storage form of lipid in milk is triglycerides; it represents between 97 and 98% of milk fat; the rest are phospholipids and cholesterol which form part of the membrane around the fat droplets (Pulina, 2002). The hydrolysis of milk fat globule triglycerides into FFA is carried out by lipoprotein lipase, an enzyme that also plays a key role in regulating the level of plasma lipoproteins in adipose and muscular tissues as well as in other body components like liver, heart and nervous system, including the mammary gland (Badaoui *et al.*, 2007). During lactation the enzyme lipoprotein lipase in the capillary walls hydrolyzes triglycerides (Sherwood *et al.*, 2005). Milk fat is synthesized either from FA from blood (60%) or by *de novo* synthesis in the mammary gland (40%) (Chilliard *et al.*, 2000). Short chain FA (C6–C10) is built *de novo* in the mammary epithelial cells from acetic acid deriving from rumen fermentation and β -hydroxybutyrate formed in the rumen wall (Sherwood *et al.*, 2005). Milk FA of chain length C-18 and above are from blood lipids which originated from fat intake in the diet and from mobilization of body fat. Medium chains (C-16) derive either from dietary lipids or from *de novo* mammary synthesis (Pulina *et al.*, 2005).

In comparison with cow milk, goat milk is much higher in medium-chain fatty acids (C8: caprylic acid and more markedly C10: capric acid) (Chilliard *et al.*, 2003). Grasses contain mostly α -linolenic acid (C18:3) whereas grain contains primarily linoleic (C18:2) and oleic acid (C18:1). These unsaturated fatty acids are also known as “essential fatty acids”; they have been shown to exert positive effects on human health; oleic and linolenic acid more particularly both have a cardioprotective effect through a direct vascular anti-allergenic action (Chilliard *et al.*, 2003). Milk fat content is high after parturition and then decreases during the major part of lactation (Chilliard *et al.*, 2003). Dunshea *et al.* (1989) supported this concept by saying that, as lactation advances, both plasma poly-unsaturated fatty acids (PUFA) concentrations and PUFA entry rates decrease. In early lactation, milk production is high and food intake is not sufficient to maintain energy balance; adipose tissues are mobilised (lipomobilisation) to provide energy for milk secretion. Fatty acids from body fat are then used extensively for milk triglyceride synthesis. If food intake is low and absorption of glucose and short-chain FA

from the intestine is drastically reduced, an animal can, for a limited period, primarily use body fat to sustain milk fat synthesis (Sherwood *et al.*, 2005).

Mobilisation of adipose tissue (lipomobilisation) in the form of PUFA and elevated plasma PUFA concentration in goats under restriction or during prolonged malnutrition was reported by Dunshea *et al.* (1989). In a recent study, Bouattour *et al.* (2008) used goats from typically dry areas and fed them a relatively high-forage diet, adding a reasonable dose of soybean oil; milk fat was increased without negative effects on intake, milk yield and protein content. This is conversant with Morand-fehr *et al.* (1980) who indicated that the inclusion of extruded soybeans to 20% of DM prevented low milk fat for goat fed high concentrate diets, with no decrease in milk protein content. In another study on mammary lipid metabolism conducted by Chilliard *et al.* (2003) it was said, and later proven, by Lefrileux *et al.* (2008) that a fat supplemented diet to goats sharply increased the percentage of milk fat, had a variable effect on protein content but did not increase milk yield. The increase in milk fat content was attributed to the net increase in fatty acids brought to the mammary gland due to the lipid supplement in the diet. However, the same study demonstrated that the higher the intake of long chain fatty acids (C18) the lower its apparent transfer rate into milk; the explanation was the higher utilization of FA by non-mammary tissues, together with a high level of incorporation into phospholipids and cholesterol ester. This suggested that part of the FA secreted into milk comes from endogenous synthesis and release by peripheral adipose tissues (Chilliard *et al.*, 2003). Changes in adipose tissue metabolism was earlier reported by Vernon *et al.* (1981) who worked on sheep and concluded that, although there were no differences between species in the time of onset of lipid mobilisation and perhaps in the regulatory mechanisms, a pattern of lipid accumulation and mobilization during pregnancy and lactation was ubiquitous among mammals.

Milk fat is an important component of the nutritional quality of goat dairy products. Goat milk fat content and composition can be extensively modified by genetic, physiological or nutritional factors. However, fat supplementation of the diet is an efficient means to modify milk FA composition in lactating ruminants (Chilliard *et al.*, 2003). In goat milk fat percentage and FFA content are highly correlated (Agnihotri *et al.*, 1993).

2.2.2.4 Milk urea nitrogen (MUN) content of goat milk

Much of the CP a ruminant consumes is degraded by rumen microbes into ammonia and used for the synthesis of microbial proteins. Ammonia is also produced from normal daily metabolism of absorbed amino acids and body proteins. Excess rumen ammonia is absorbed by the rumen wall and ammonia from tissue metabolism transported in blood to the liver and kidneys where it is converted into urea. Some of the urea circulating in blood is recycled in the saliva back to the rumen. Excess ammonia circulating in blood is very toxic, whereas urea is much less so. The conversion of blood ammonia into urea occurs in mammals as part of their normal body metabolic mechanism to prevent ammonia toxicity (Bonanno *et al.*, 2008). These views were already reported by Oltner *et al.* (1983). Work conducted by Kohn *et al.* (2005) who used BUN to predict nitrogen excretion and efficiency of nitrogen utilization in goats, resulted in the finding, later supported by Arunvipas *et al.* (2007) that blood and plasma urea concentrations are proportional to MUN, they may therefore be useful as predictor in much the same way.

In conclusion, high blood nitrogen concentration is typical during lactation and because of the high positive correlation between plasma and milk urea (Khaled *et al.*, 1999), MUN can be used as an indirect indicator of protein in the diet especially for animals at pasture in which evaluating protein in the diet is particularly difficult (Pulina, 2002; Cannas *et al.*, 1997; Van der Merwe *et al.*, 2001; Caldeira *et al.*, 2007; Broderick *et al.*, 2007; Giaccone *et al.*, 2007; Sahoo *et al.*, 2008)

2.2.2.5 Somatic cell counts (SCC) of goat milk

Milk always contains leukocytes and dislodged mammary epithelial cells; the normal somatic cells that are sloughed off by the normal “somatic cells” secretion in goats consist of cytoplasmic particles which break off and are shed with milk (Das *et al.*, 2000). Only 10% of the somatic cells are mammary gland cells (eosinophils, epithelial cells) normally secreted together with milk as a result of cellular turnover in the mammary gland; the remaining 90% of the somatic cells are blood cells (macrophages,

leucocytes, lymphocytes) which contribute to the immune defence of the mammary gland; their number increases considerably in the case of inflammatory or pathological processes as in mastitis (Bencini *et al.*, 1997). In healthy cows there are approximately 30,000 to 300,000 cells per ml of milk. Normally half of the somatic cells are neutrophile granulocytes; but during inflammation of the udder the density of the somatic cells in milk increases 10 to 100 times.

Milk somatic cell count (SCC) has been used as a tool for assessing both animal health status and milk quality (Casu *et al.*, 2010). Many authors (Zeng *et al.*, 1995; Zeng *et al.*, 1996; Voutsinas *et al.* 1990) have indicated that SCC and daily milk yield vary throughout lactation depending on numerous factors such as morning versus evening milkings, stage of lactation, parity and breed. The SCC of goat milk is generally greater compared with the dairy cows (Chang *et al.*, 2006). Since the concept of “Grade Pasteurized Milk Ordinance (PMO)” was popularized in the United States (US) in 1989, the US PMO regulation regarding SCC in goat milk allows $1 \times 10^6 \text{ ml}^{-1}$ while the legal Milk SCC (MSCC) limit established by the US Food and Drug Administration (FDA) is of 10^6 for sheep and goat (Paape *et al.*, 2007). In South Africa the legal limit of SCC is set at 750×10^3 cells per ml (Petzer *et al.*, 2008). In dairy cows the concentration of more than $750,000 \text{ ml}^{-1}$ SCC in milk is considered indicative of mastitis in the mammary glands (Zeng *et al.*, 1995). This figure may not necessarily be applicable in dairy goats, where milk of individual infected and non-infected does often contained more than 1×10^6 SCC ml. Zeng *et al.* (1995) reported that 56% of milking does produced milk with $1 \times 10^6 \text{ SCC ml}^{-1}$; they concluded that milk from healthy does, with no signs of mastitis could contain as many as $5 \times 10^6 \text{ SCC ml}^{-1}$.

They explained that dairy goats have a different secretory system than cows. The apocrine system of goats produce cytoplasmic particles and their milk may contain a large number of epithelial cells resulting in the exceeded limit of SCC especially in their late lactation stage. The same authors (Zeng *et al.*, 1995) reported an average of 1.3×10^6 SCC in bulk tank goat milk collected in November and December and that significant variations in SCC among goat herds existed ranging from 4.38×10^5 to 1.68×10^6 ; after examining a complete lactation of Alpine goats (March to October) they concluded that parity did not affect SCC or chemical composition of milk; and also that SCC of more

than 1 million ml⁻¹ did not indicate any mastitic conditions in alpine goats. In a study conducted by Das *et al.* (1999) on variation in blood leucocytes, SCC in milk yield and composition of crossbred goats revealed that mean SCC was higher in the first biweekly period of lactation and declined steadily with advanced lactation; but in individual goats, considerable variation (8.09-44.10 x 10⁵ cells/ml) existed. Furthermore, variation in SCC between the goats and between different experimental periods was highly significant ($P < 0.01$) just as it was ($P < 0.05$) between the two different breeds of goats used in the experiment.

Paape *et al.* (2006) said that there was no Milk SCC legal limit for sheep and Goat in the European Community. Mena *et al.* (1999) expressed the hope that the European Union will establish the SCC limit at 1.5 x 10⁶ cells/ml. Corrales *et al.* (2004) indicated that the limit of 1.5 x 10⁶ cells/ml should be acceptable for goats' milk in the European Union. No official maximum threshold is reported for goat milk SCC in Mexico, which is the main goat milk producer on the American continent (Fernandez *et al.*, 2008).

In summary SCC is certainly a valuable udder health status index, but up to which threshold exactly it can be used in the dairy goat is still to be established.

2.2.3. Selected blood metabolites associated with milk production.

Blood chemistry has long been used in human medicine as a diagnostic tool. With the development of new automated analytical equipment in the sixties blood chemistry became a routine technique for the assessment of metabolic status in individuals and groups of animals. Payne (1978) grouped different blood constituents into a single package called the "Compton metabolic profile test". Rowlands (1980) introduced the concept of "blood profile" defined as a set or combination of blood constituents analyzed together depending on factors such as relevance to the problem under investigation, cost and ease of analysis and stability of samples in relation to time in transit between farm and laboratory. The blood constituents usually analyzed were PCV (packed cell volume), haemoglobin, glucose, urea nitrogen, albumin, total protein, calcium, magnesium, sodium, copper and iron. Later, free fatty acid and cholesterol were added to the blood profile because of their relationship to energy status (Ingraham *et al.*, 1988). Pambu (1997) used blood glucose, blood urea nitrogen, blood cholesterol and total protein

concentrations to evaluate the nutritional plane of indigenous goats raised on free ranging system in South Africa.

In this study, glucose, BUN, cholesterol and FFA concentrations have been selected firstly, because of their pertinence to the energy metabolism of the ruminant and secondly, because of the association of urea to the protein and nitrogenous metabolism. In the milk industry indeed, a premium is paid for the protein, lactose and fat percentage in milk.

2.2.3.1 Blood glucose concentration in goats

Glucose is synthesized from four glucose precursors: propionate, amino acids, glycerol and lactate. An abundant scientific literature supports propionate and amino acids as the most important contributors to glucose synthesis. Lindsay (1971) and Bergman (1983) said that between 45 and 75% of the total glucose produced derived from propionate and amino acids. Donna *et al.* (1990) and Weekes (1991) suggested that between 20 and 56% of the total glucose synthesized derived from propionate. Eisemann *et al.* (1994) claimed that, of the total body glucose production, 85% arose from the liver; 90% of all the propionate produced is removed by the liver for glucose synthesis. Findings of Bickerstaffe *et al.* (1974) established earlier that the hepatic glucose production derived mainly from propionate and glucogenic amino acids, namely alanine and glutamine: the two major amino acids used for glucose synthesis. Of the total glucose production, between 15 and 32% originated from amino acids (exogenous) source or, (in case of food deprivation) from muscle protein catabolism whereby the carbon skeletons of the amino acids released were used for gluconeogenesis, while nitrogen was converted into urea and excreted in the urine (Bergman, 1983).

Glucose from the gastro-intestinal absorption represents between 0 and 6% of the total glucose turnover (Sutton, 1985). The major part of dietary glucose is used as a source of energy by the gut and little, if any of it, reaches the liver (Bergman, 1983; Weekes, 1991; Balcells *et al.*, 1995). Hormones related to glucose metabolism are insulin, glucagon and growth hormone. The capacity of insulin to suppress endogenous glucose output is well documented (Weekes, 1991; Chang *et al.*, 1996). Eisemann *et al.* (1994) showed that the total splanchnic release of glucose declined linearly as amount of

infused insulin was increased. Glucagon is associated with an increase in blood glucose concentration. It (glucagon) causes glycogenolysis followed by gluconeogenesis. If glucagon fails to raise blood glucose concentration sufficiently, epinephrine is secreted from the adrenal medulla. The combined effect of these hormones will increase glycogenolysis and lipolysis. Glycerol will be mobilised and free fatty acids will become available as an alternative fuel for oxidation. The overall result will be an increased blood glucose concentration. The other important hormones in this respect are cortisol, growth hormone and prolactin. While cortisol and growth hormone increase protein catabolism (and therefore glucose concentration), prolactin mobilizes adipose lipid stores. This in turn results in an increased concentration of glucose precursors (Baumann *et al.*, 1980).

Under normal circumstances, between 20 and 30% of the total glucose production is oxidized by the ruminant brain. Up to 10% is converted into glycogen by the liver, while up to 30% is deposited as fat. The remainder is used as an energy source by muscle. During pregnancy fetal oxidative metabolism removes up to 40% of total maternal glucose production, while between 85 and 90% is taken up by the mammary gland during lactation (Baumann *et al.*, 1980; Bergman, 1983; Weekes, 1991). The apparent contribution to mammary gland metabolism is:

- Glucose>Acetate> β -hydroxybutyrate>FFA for the lactation phase; and
- Acetate> β -hydroxybutyrate>Triacylglycerols for the involution stage, with no positive uptake of glucose and FFA (Chang *et al.*, 1996).

The primary requirement of glucose by the mammary gland during lactation is to serve as a precursor to lactose synthesis (Rook *et al.*, 1966). Lindsay (1971) showed that food intake is a major determinant of increased blood glucose production during lactation; this was also the view of Sahlu *et al.* (1992) who observed high glucose concentrations in goat fed high energy diets; apparently, an increased glucose production resulted from greater availability of glucogenic AA present in the diet. Many authors (Bergman, 1983; Weekes, 1991; Hossaini-hilali *et al.*, 1993; Landau *et al.*, 1993 and Rusche *et al.*, 1993) showed that increased food intake resulted in high blood glucose

concentration in lactating animals. In contrast, a low blood glucose concentration during lactation was reported (Rowlands, 1980; Manston *et al.*, 1980); this decrease, according to Ingraham *et al.* (1988), commonly observed in high yielding cows, can be attributed to the fact that during early lactation the ruminants are unable to eat sufficient food to meet their high metabolic demand; this put the high producing animal in a critical nutrient balance and affects blood metabolites concentrations for 60 days more after calving.

Glucose and cholesterol are among the blood constituents that are most affected. Amaral Phillips *et al.* (1993) investigated the short-term effects of decreased availability of glucose in dairy cows. It was concluded that fat and protein are mobilized from adipose and muscle tissue to provide gluconeogenic precursors after reserves of liver glycogen are depleted. Hossaini-Hilali *et al.* (1993) observed that plasma glucose concentrations decreased more rapidly in lactating than in non-lactating goats because more glucose was used for lactose synthesis in the lactating goats resulting in a depletion of the glucose pool.

These results were later supported by Hussain *et al.* (1996) who showed that plasma glucose concentrations were lower in the underfed goats as compared to the well fed group. From the above, it can be concluded that a low blood glucose concentration is typical of lactation (Rowlands, 1980; Ingraham *et al.*, 1988) but in case of an imbalance between supply and demand during lactation, body reserves are mobilized, followed by increased blood glucose concentration. In this case animals will display a higher than expected blood glucose concentration accompanied by high level of urea nitrogen concentration.

Glucose is critical during lactation because its uptake by the mammary gland is essential for the synthesis of milk lactose, the major osmotic regulator of milk volume. The pancreatic hormones insulin and glucagon are key controls of glucose homeostasis: acute regulation of plasma glucose concentration by reciprocal actions of insulin and glucagon ensure the proper balance in glucose supply and utilization by body tissues and organs during lactation (Bauman *et al.*, 1980).

Blood glucose concentrations have been, on one hand, used by some as an index of energy status in ruminants (Payne, 1970; Rowlands, 1980; Ingraham *et al.*, 1988; Pambu *et al.*, 2000). On the other hand, Erfle *et al.* (1974) and Russel (1983) have

warned that blood glucose concentrations, because of their sensitivity to homeostatic control and also to adrenal cortical influence, are unsatisfactory as an index of energy status. Lately, Caldeira *et al.* (2007) wrote that the ruminant energy status predictors included plasma and serum glucose, insulin, glucagon, non-esterified fatty acids (NEFA) β -hydroxybutyrate, triacylglycerols and total lipids.

From all these, glucose, NEFA and insulin provided more substantial information for the diagnosis of the animal's energy status. Blood glucose and blood urea nitrogen concentrations can be used to monitor nutrient status in goats (Turner *et al.*, 2005). In this study, they have been selected to evaluate the adequacy of energy intake in lactating goats raised in small scale farming systems.

2.2.3.2 Blood urea nitrogen (BUN) concentration in goats

Most of the Non-Protein Nitrogen (NPN) and protein material ingested by the ruminant are degraded by the rumen microbiota into ammonia (NH_3) which is readily absorbed through the lining of the rumen reticulum and omasum (Bonanno *et al.*, 2008). Rumen microbes use ammonia along with some amino acids and polypeptides to synthesize their own microbial proteins. Once these bacteria are swept into the abomasum, their cell proteins are digested and eventually absorbed through the small intestine.

The synthesis of microbial proteins also ensures that the host animal is supplied with essential as well as non-essential AA (Sherwood *et al.*, 2005). Between 30 and 40% of dietary protein entering the rumen is not degraded and is classified as rumen-undegradable protein (RUP) which can be hydrolysed only by the gastrointestinal proteolytic enzymes. Ammonia generated in the reticulo-rumen is either converted into microbial proteins or converted into urea in the liver. Some of this urea is returned to the forestomach directly through the wall of the reticulo-rumen or through the salivary glands. High urease (urea-digesting) activity is found along the ruminal wall and is responsible for the rapid degradation of urea to ammonia for metabolism into microbial proteins (Bonanno *et al.*, 2008).

When environmental conditions become particularly harsh and the only herbage available is deficient in protein, the concentration of ammonia in the rumen is low, as are

the number of rumen microbes; the breakdown of cellulose will slow down; the total amount of nitrogen returned to the rumen as urea exceeds that absorbed from the rumen as ammonia, nitrogen recovered through this process is converted to microbial proteins. Ultimately the total amount of protein arriving in the intestine can be greater than that of the original food. A ruminant can conserve an important nitrogen source by returning to the rumen urea that would otherwise have been excreted as urine (Goshtasbpour-Parsi *et al.*, 1974). Alternatively in conditions where protein degradation is greater than its synthesis, such as in animals fed rich concentrates, ammonia can potentially accumulate in the rumen fluid, be converted into urea in the liver before excretion in urine and be wasted (Sherwood *et al.*, 2005); in the Angora and the Boer goat for example, between 38 and 58% of urea influx can be lost in this way (Cronje *et al.*, 1992). During fasting or inadequate nutrient intake, the animal mobilizes body reserves (muscle protein catabolism) and amino acids (AA) become available (Folman *et al.*, 1981). In goats, this all sequence of events has been represented by Harmeyer *et al.* (1980) on Figure 1.1 (below).

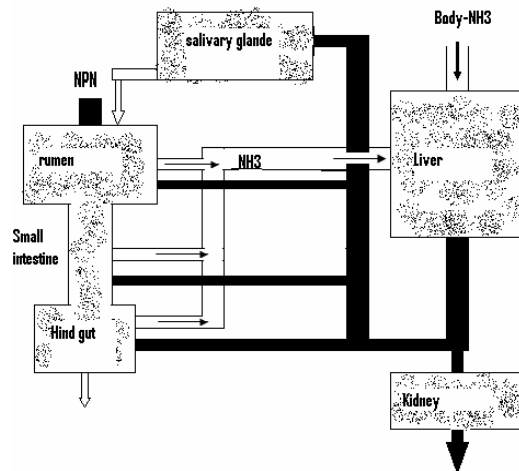


Figure 1.1: Diagrammatic illustration of urea metabolism in the goat (Harmeyer and Martens, 1980)

Deamination of the AA (from Body reserves) for gluconeogenesis in the liver will result in the production of urea (Ganong, 1995). Gluconeogenesis and ureogenesis are therefore linked processes (Bergman, 1983; Belyea *et al.*, 1990). Of the urea synthesized in the liver, between 30% and 58% can result from deamination of amino acids (Nolan *et*

al., 1972; Lindsay, 1971). In goats as in other ruminants, renal mechanisms may also contribute to urea conservation during protein deprivation (Eriksson *et al.*, 1981).

The hormonal factors affecting blood urea concentration are linked to those affecting blood glucose concentrations. When blood glucose concentration falls, the insulin: glucagon ratio decreases in favor of glucagon which will stimulate breakdown of amino acids from muscles (Bergman, 1983). The AA carbon skeleton will be used to synthesize glucose, while the amino radicals will be converted into urea, resulting in an increased blood urea concentration. Glucagon, cortisol and growth hormone influence blood urea concentration indirectly. Glucagon in particular can increase the uptake of alanine, glutamine and other glucogenic amino acids by the liver (Bergman, 1983). If the chronic food shortage continues, long-term hormonal adjustments will take place resulting in increased secretion of epinephrine (Bergman, 1983).

The association between the reduced insulin secretion and the glucagon plus epinephrine secretion will further increase glycogenolysis and rapidly cause lipolysis in adipose tissue followed by mobilization of glycerol and free fatty acids. The increased supply of glycerol will in turn increase gluconeogenesis and the free fatty acids released will provide alternative fuel for oxidation by the body (Bergman, 1983; Ganong, 2005). Schrick *et al.* (1990) fed Angus and polled Hereford cows' diets of high or low energy content and studied the effect of dietary energy restriction on metabolic and endocrine responses during estrus cycle of suckled beef cows. Cows fed the low energy content diet had higher blood urea nitrogen concentrations. This was explained by the fact that those animals were in a state of energy deficiency; muscle protein was catabolised to produce AA which in turn contributed to a gluconeogenesis and the subsequent ureogenesis. It indeed appears that high BUN concentration is typical during lactation. This is not only because of the increased rate of urea recycling to the reticulo-rumen but also because of the negative energy balance which occurs during early lactation and which results in AA deamination and consequently in gluconeogenesis and the subsequent ureogenesis (Brun-Bellut, 1996).

Similar conditions prevailed when Khaled *et al.* (1999) investigated the changes in the concentration of blood and milk constituents of dairy goats under the effects of stable diets. They found a high amount of serum NEFA, blood total ketones and BUN

concentration in the first lactation months and concluded that this was subsequent to the energy deficit associated to the considerable metabolic changes occurring in the high yielding dairy goats. Hoaglund *et al.* (1992) studied the effects of supplemental protein source and metabolizable energy intake on nutritional status in pregnant ewes. It appeared that BUN (and albumin) concentrations were higher in ewes fed blood meal plus soybean meal than in ewes fed soybean meal or urea only. These results are in agreement with those of Palmquist *et al.* (1978); Park (1985); Dhiman *et al.* (1991); Nikokirys *et al.* (1991); Rusche *et al.* (1993); Sahlu *et al.* (1993); and Diab *et al.* (1996) who indicated :

- 1) That an increased BUN concentration can result from increased dietary crude protein intake, and that a low crude protein intake is associated with low BUN
- 2) That a low dietary energy supply is also associated with higher BUN concentration as a result of the mobilization of body reserves for gluconeogenesis and the subsequent ureogenesis;
- 3) That BUN can possibly be used as an index of fertility in cows fed excess ruminally degradable protein.

Caldeira *et al.* (2007) wrote that the protein status predictors included serum albumin, globulins, total protein, urea and creatinine. Of these, serum albumin and urea concentrations are good metabolic indicators of the animal's protein status. This is also the opinion of Kohn *et al.* (2005) who claimed that BUN concentration may be useful as a protein status index. In the present study, BUN concentration has been selected to evaluate the adequacy of protein intake in lactating goats raised on small scale farming system.

2.2.3.3 Blood Cholesterol concentration in goats.

Cholesterol biosynthesis can take place in several organs, the liver and the intestines being the most important sites of production. A distinction must be made between dietary (exogenous) cholesterol and endogenous cholesterol (from extrahepatic tissue synthesis) (Beynen *et al.*, 2000). It has been shown that dietary saturated fat elevates plasma cholesterol concentrations in many species (Diersen-schade *et al.*, 1984) and the easiness with which dietary cholesterol enters and crosses membranes in the

animal body has been demonstrated by Raphael *et al.* (1975). Dietary cholesterol esters in the intestinal lumen are converted into cholesterol by pancreatic cholesterol ester-hydrolase. The free cholesterol produced, together with free cholesterol in the diet and in the bile, is taken up by absorptive cells in the mucosa of the small intestine. Here cholesterol is re-esterified into cholesterol-esters, and these are transported via the lymph in chylomicrons (Kaneko, 1989). The nascent chylomicrons enter the blood via the lymphatic ducts before disposing of their triacylglycerols into tissues such as adipose tissues (Ganong, 2005).

The chylomicron remnant brings cholesterol to the liver. From the liver, cholesterol is dispatched to different extrahepatic organs (intestines, adrenals, kidneys, heart, mammary glands, lung, ovaries, skin, muscle and brain). In the liver, cholesterol is also incorporated (as such, or after transformation) into bile. Bile is secreted into the small intestine where cholesterol will be either reabsorbed in the intestinal mucosa, or excreted in the faeces (Dietschy *et al.*, 1995). An additional source of cholesterol is acetate, one of the three VFA's resulting from the dietary carbohydrates fermentation in the rumen. In this case, part of acetate circulating in the peripheral blood is removed from the portal blood in the liver where it is used for *de novo* synthesis of the long-chain fatty acids and cholesterol. In the peripheral organs (muscle, portal drain viscera, adipose tissue as well as in the liver) acetate will be oxidized and *de novo* synthesized cholesterol will result from acetyl CoA (Miller *et al.*, 1991). In plasma, cholesterol is carried in lipoprotein complexes known as VLDL (very low density lipoproteins) LDL (low density lipoproteins) and HDL (high density lipoproteins) (Beynen *et al.*, 1989). The cholesterol portion carried in chylomicrons and delivered to the liver is incorporated into VLDL-cholesterol which in turn will bring triacylglycerols to peripheral tissues for oxidation; in this process VLDL-cholesterol will be transformed into LDL-cholesterol which will be reabsorbed mainly (80%) by the hepatic LDL-receptors and at the lower rate by the adrenals. It is believed that cholesterol from peripheral synthesis is the most important contributor to the total cholesterol turnover. This sequence of events is shown in Figure 1.2 represented on next page.

As said earlier, cholesterol is used in the liver (as such, and as bile acid precursor); at this level, any cholesterol that cannot be reabsorbed will exit the body via faeces (Beynen,

2000). As a steroid hormone precursor, cholesterol used by various organs (ovaries, adrenals) is excreted from the body in the urine. The role of cholesterol as a structural component of most cell membranes and as a vitamin D precursor is also well documented; as such, it is essential for animals from which it is lost through sloughing of the intestinal mucosa and the skin (Zubay, 1986).

The cholesterol content of milk in the goat is usually in the range of 10 to 20mg/100ml (Jenness, 1980). The cholesterol content of colostrum is much higher (40mg/100ml). Milk cholesterol may derive from blood or from *de novo* synthesis from acetate within the mammary gland (Long *et al.*, 1980). Although milk cholesterol is synthesized in the mammary gland, it derives principally from serum cholesterol which equilibrates with membrane cholesterol of the lactating cell prior its secretion in milk (Long *et al.*, 1980).

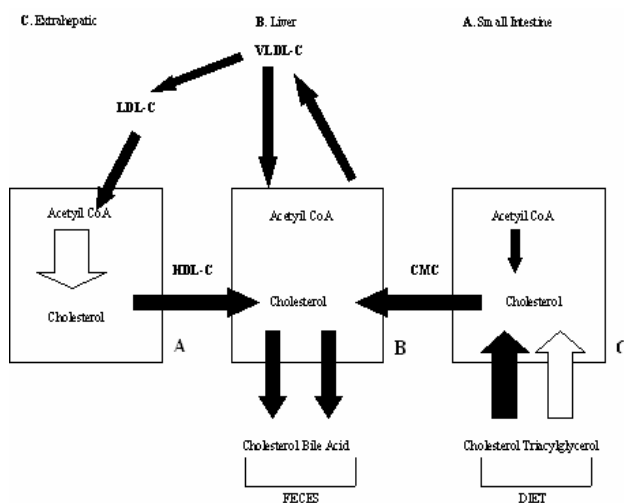


Figure 1.2: Cholesterol metabolism in cynomolgus monkeys (Source: Turley, Spady & Dietschy, 1995)

The demand for cholesterol by the mammary gland will differ according to the stage of lactation, with particularly acute changes occurring at the onset and cessation of lactation. The uptake of cholesterol from plasma lipoproteins is increased during lactation (Botham *et al.*, 1993). In goats, chylomicrons make an important contribution to mammary lipid uptake (Bickerstaffe *et al.*, 1974). In most cases, the liver functions to present a constant concentration of cholesterol to the extrahepatic tissues. Consequently, under normal situations, the hepatic cholesterol contribution is a reflection of the balance

between the demand by various tissues and the supply of exogenous and endogenous cholesterol. If the dietary cholesterol content is increased, hepatic cholesterol synthesis will decrease and faecal loss will increase so that equilibrium is maintained. On the other hand, if a low-cholesterol cellulose diet is fed, the plasma cholesterol concentration will be low (McCall *et al.*, 1992), and the hepatic cholesterol contribution will be increased (Dietschy *et al.*, 1995). During pregnancy or lactation, however, the higher cholesterol demand exceeds the hepatic compensatory capacity (Ruegg *et al.*, 1992; Nielsen *et al.*, 1994). If the extra cholesterol required is not supplied through the diet, a negative energy balance will result with a drop (below 50mg/dl) in the total cholesterol concentration (Dietschy *et al.*, 1995).

The reverse is also true: lipid-rich diets result in an increased amount of cholesterol reaching the liver which will in turn, raise the plasma cholesterol concentration (Yang *et al.*, 1978; Grummer and Carroll, 1988; Ruegg *et al.*, 1992; Kadzere *et al.*, 1993; Lin *et al.*, 1994; Dietschy *et al.*, 1995). There are also cases (starvation, food scarcity) where the animal has to mobilize body reserves; blood cholesterol concentration will, under such circumstances, be elevated (Grimoldi *et al.*, 1988).

A number of authors (Yang *et al.*, 1978; Grummer *et al.*, 1988; Hiromasa *et al.*, 1990; Caldeira *et al.*, 1991; Ruegg *et al.*, 1992; Lin *et al.*, 1994; Miettinen *et al.*, 1994; Weiss *et al.*, 1994) have shown that a higher plasma cholesterol concentration is caused by feeding lipid rich diets, or diets rich in cholesterol precursors. Others (Ingraham *et al.*, 1988; Ruegg *et al.*, 1992) have indicated that high cholesterol concentrations in the absence of excess dietary fat intake are a reflection of the capacity of the animal to mobilize body energy reserves. Nachtomi *et al.* (1991) found that blood cholesterol concentrations increased during the first five weeks of lactation in high producing dairy cows. A possible explanation is that the increased demand for energy required for production of milk and milk fat resulted in fat mobilization from fat reserves; this was in turn followed by an increase in blood cholesterol concentration as has been reported by Grimoldi *et al.* (1988). Wiley *et al.* (1991) found that cholesterol concentrations were lower in first calf beef heifers fed undegradable protein than in heifers fed rumen degradable protein. Although the relationship between protein and cholesterol is not well

defined, Park (1985) suggested that the amount of protein ingested affected the rate of cholesterolgenesis. The results of Wiley *et al.* (1991) can possibly be explained in the light of the assumption that the solubility of protein may have an effect on the rate of cholesterolgenesis. Arave *et al.* (1974) studied the genetic and environmental effects on serum cholesterol concentrations of dairy cattle of various ages. It was found that serum cholesterol concentrations were relatively low at the onset of lactation, increased at mid-lactation and levelled off or decreased in late lactation. This was in agreement with Rowlands *et al.* (1980) who studied metabolic changes in dairy cows during pregnancy and late lactation and found a significant increase in blood cholesterol concentrations between week one and six post- partum.

From the above, it can be concluded that blood cholesterol concentration is affected by lactation especially in early lactation, and also in the case of body reserves mobilization; blood cholesterol concentration is however, complicated by the relationship between cholesterol concentrations and hormones involved in reproduction. In the present study blood cholesterol concentration has been used to evaluate the adequacy of energy intake in lactating indigenous goats raised in small scale farming system.

2.2.3.4 Blood free fatty acids (FFA) concentration in goats

The major fats in grains are triglycerides that contain a high proportion of linoleic acid (C:18:3) whereas in forages the lipids are in the form of galactoglycerides whose main fatty acid is linolenic acid (C: 18: 2). Most forages and seeds or grains do not contain high proportions of lipids; only about 40 to 60g per kg DM. These lipids contain a high proportion of residues of the C:18 poly-unsaturated fatty acids, namely linoleic and linolenic acids. Grasses contain more α -linolenic acid (C18:3) whereas grains contain primarily linoleic (C18:2) and oleic acids (C18:1). In ruminants, more than 90% of triacylglycerides and other plant lipids in feed are hydrolyzed in the rumen and more than 90% of these unsaturated fatty acids are completely hydrogenated in the forestomach, forming stearic acid (C18:0) (Meissner, 1994).

In most animals, between 40 and 50% of fatty acids used by the mammary gland for milk fat synthesis are produced in the mammary epithelial cells by *de novo* synthesis from smaller components such as acetate in ruminant and glucose in single-stomached

animals; the other half of fatty acids are taken up from the blood. Esterification of fatty acids takes place in the endoplasmic reticulum of the cells; the reaction utilizes α -glycerophosphate which is formed in the cells from glucose or from glycerol (Zubay, 1986). Mono and Di-glycerides taken up from blood are also esterified; the short-chain fatty acids (C4) are esterified primarily to carbon 1 and 3 in the glycerol molecule, while the long chain fatty acids bind to the middle carbon atom in position (C2). Nearly all the fatty acid molecules in milk are esterified. Newly synthesized milk therefore has very low concentrations of free, unesterified fatty acids (Sherwood *et al.*, 2005). Milk fat per cent and FFA contents are highly correlated in goat milk (Agnihotri *et al.*, 1993).

In early lactation, milk production is high and food intake is not sufficient to maintain energy balance. Fatty acids from body fat are then used extensively for milk triglycerides synthesis (Chilliard *et al.*, 2000; Doepel *et al.*, 2002). If food intake is low and absorption of glucose and short chain fatty acids from the intestines is drastically reduced, an animal will, for a limited time, primarily use body fat to sustain milk synthesis. During *de novo* synthesis the udder epithelial cells form fatty acids from precursors like acetate and β -hydroxybutyrate formed in the rumen wall. Precursors for the lipids synthesized and secreted by the mammary epithelial cells are therefore from the diet or from adipose tissues (Sherwood *et al.*, 2005).

Miettinen *et al.* (1989) worked on the concentrations of blood metabolites and their relation with fatty acids composition of dairy cow milk; it was found that milk fatty acids *de novo* synthesized (C6-C16) were positively correlated (while the long chain fatty acids (C16) entirely derived from blood were negatively correlated) to the estimated metabolizable energy balance. It was concluded that blood aceto-acetate and plasma NEFA and glucose concentrations are the best indicators of the cow's energy status. This is in agreement with Dunshea *et al.* (1989) who studied the relations between plasma NEFA metabolism and body tissue mobilization during chronic undernutrition in goats; not only did they write that plasma NEFA concentrations could be used as an index of chronic energy status, but they also observed an elevated NEFA concentration during acute energy restriction; the explanation was that adipose tissue was mobilized in the form of NEFA.

An elevated milk fat content after parturition with a decrease during the major part of lactation in goats was also observed by Chilliard *et al.* (2003). Bernard *et al.* (2005) studied the mammary lipid metabolism and milk fatty acid secretion in Alpine goats and found that a fat supplemented diet to goats sharply increased the percentage of milk fat but did not increase milk yield; and also that plasma NEFA in lactating goats was not influenced by diet differing in type and level of fat, contrasting with the increase of plasma NEFA observed by Rukkwamsuk *et al.* (1998) in cows receiving dietary fat. It was suggested that regulation of mammary cells do differ between caprine and bovine species, particularly in the elongation process of fatty acids which are *de novo* synthesized by the “fatty acid synthetase” complex; for this reason the homeorhetic control on the lactating goat may have set mechanisms whereby milk fat precursors were derived primarily from the body reserves and indirectly only from dietary fat. This non-responsive attitude of lactating goat fed rich-fat diet was also observed by Luna *et al.* (2008) when they studied the effect of diet enriched in whole linseed and sunflower oil on goat milk fatty acids composition. Certain diets cause a marked reduction in milk fat production in ruminants (Bauman *et al.*, 2003)

The nutritional advantage of goat milk fat compared to cow milk has been attributed to the high content of caproic acid (C6) and capric acid (C10), to its lack of agglutinin, and to its high percentage of short and medium chain fatty acids esterified on carbon 3 of the glycerol skeleton and also to the small size of its fat globule (Luna *et al.*, 2008). For this reason, a lot of interest has been shown in goat milk fatty acids composition and many attempts to modify them through nutrition have been made in order to derive a quantitative advantage on goat milk products. However, it seems that such changes, may adversely affect the flavour and nutritional properties of dairy goat products (Luna *et al.*, 2008).

2.3. Phenotype score (PTS)

The concept of phenotype score (PTS) is new. It has been developed as a tool to assist the goat farmers who want to make predictions on their lactating does’ (quantitative and qualitative) milking potentialities. PTS has been also developed as an instrument to

help the farmers fine-tune management decisions in order to improve their goat milking productivity. PTS consists in a critical analysis of data gathered from the BCS, breed, udder characteristics and age, their interactions and their implication at the metabolic (therefore their productivity) level. In practice PTS does not yet exist; whence the limited literature dealing with this subject; however, BCS is quite well documented while reports on goats' phenotype characteristics (breed, udder characteristics) and age are scanty and remain substantially limited.

2.3.1 Body condition scoring (BCS) in goats

It is generally acknowledged that live weight and body condition are connected to productivity in the ruminant (Majele-Sibanda *et al.*, 2000). Body condition scoring is a fairly simple and efficient tool to assess the health and nutritional status of animals (Nix, 2004). It is used to evaluate an animal's body fat in relation to the amount of muscle it possesses (Coffey *et al.*, 2009). The term "body condition" refers to the fleshiness of an animal (Luginbuhl *et al.*, 2009). It is an estimate of the muscle and fat development of an animal (Cobb, 2008). Animal body condition is considered to be an indicator of fat reserves; and fat reserves in animals reflect the production performance of the herd (Santucci *et al.*, 1991). It involves the visual appraisal and (or) palpating certain areas of the animal's body and assigning to the animal a numerical score on a five-point scale: 1 (for an extremely thin animal) to 5 (for a very over-conditioned – obese – animal) (Garcia *et al.*, 2008). In the specific case of goats, BCS has been recognized as an important practical tool in assessing the goat's body general appearance, because BCS is the best simple indicator of the fat reserves which can be used by the animals in periods of high energy demand, stress or suboptimal nutritional conditions (Sahlu *et al.*, 2007). BCS may be helpful in three ways: i) assessment of the relative changes in body composition may help in evaluation of nutritional status, leading to the determination of the adequate period of reproduction and to an optimal management of feed supplementation. ii) BCS may be a tool to assess acceptability of carcasses for meat markets (Aumont *et al.*, 1994). iii) Under farm conditions BCS is an important tool to assess the adequacy of feeding programmes (Caldeira *et al.*, 2007). When overall body condition starts to decrease in the goats, it is a sign that managerial intervention such as supplemental feeding, deworming

or pasture rotation is needed. Conversely, when overall body condition starts to increase in the herd, it is a sign that the producer should reduce supplemental feeding. Goats need to be maintained at a moderate amount of body condition (Caldeira *et al.*, 1991). BCS is therefore a useful tool to manage food in the herd (Pennington, 2009).

However, some authors regard BCS as a subjective estimate (Halachmi *et al.*, 2008; Hady *et al.*, 1994; Garcia *et al.*, 2008). Factors such as the evaluator, gut fill, amount of hair and amount of muscle can mask the true body condition of the animal (Coffey *et al.*, 2009). Moreover, it can be difficult to make an accurate estimate of the goat's body condition, especially in dairy goats, which deposit much of their fat intra abdominally and are naturally bony and scrawny looking (Catton *et al.*, 2002); goats have indeed the ability to deposit considerable fat internally and this may lessen the accuracy with which body composition can be predicted from BCS (Ngwa *et al.*, 2007). Other authors (Van Niekerk *et al.*, 1988; Eknaes *et al.*, 2006; Luginbuhl *et al.*, 2009) have also supported the opinion that simply looking at a goat and assigning its BCS can easily be misleading. BCS cannot be assigned by simply looking at the animal, instead the animal must be touched and felt (Sahlu *et al.*, 2007). One example that BCS is too simple an estimation is that, in the US, only 5% of the dairy herd managers do assign a BCS to their cows (Schultz *et al.*, 2008).

2.3.2 Breed

The goat world population is estimated at 746 million (FAOSTAT, 2010) in which approximately 300 breeds of goat have been identified. In Africa, goats are generally divided between meat, dairy and dual purpose breeds. Most goats however, still serve multipurpose functions for their owners. Very few breed-improvement programs have been made to develop the goats for more specialized economic functions such as meat or milk production (Mba *et al.*, 1975; Ahuya *et al.*, 2009). Notwithstanding the above, in South Africa, goats are grouped into four categories: i) the Angora goats, basis of the mohair industry; ii) the dairy goats namely, the Saanen, the Toggenburg and the Alpine breeds; iii) the Improved Boer goat, a cross between the African, the Dutch and the Indian breeds developed in the Eastern Cape iv) the Indigenous goats, which are widely distributed throughout the country are extremely popular in the communal rural areas

(Mammabolo *et al.*, 1998). Worldwide, Devendra (1980) has reported the following breeds as being well-known for their high milk yielding capacity: i) The Saanen (UK) : 1227 kg/milk/365 days ii) The Anglo-Nubian (UK): 989 kg/milk/ 365 days iii) The Damascus (Cyprus): 300-600 kg/milk/ 240 days iv) The Jamnapari (India): 235 kg/milk/ 261 days v) The Barbari (India): 144kg/milk/235 days. vi) and The Sudanese Nubian (Sudan): 40 kg/milk/lactation.

Among the European breeds raised in the tropics attention should be focused on the Anglo-Nubian, the Toggenburg, the British Alpines and the Saanen (Devendra, 1980). The Alpines, Saanen and Toggenburg breeds originated in the French and Swiss Alps; they are referred to as “Swiss” type breeds (Harris *et al.*, 2003); nowadays, they are also found in South Africa. In this study, these breeds have been selected and raised together with the indigenous goats in a small scale farming system at the (Agricultural Research Council) Animal production institute of Irene, nearby Pretoria.

2.3.3 Udder characteristics

This term refers to the udder circumference (perimeter) and udder depth, traits that describe the udder volume (size); it also includes the length, the cleft and the level of attachment of the udder. A phenotypic correlation has been found between these traits and milk production (Mavrogenis *et al.*, 1989). Montaldo *et al.* (1993) worked on phenotypic relationships between udder and milking characteristics; they found that globular (maximum perimeter) udders had a significant positive correlation with daily milk production. Peris *et al.* (1999) studied the relation between udder and milking traits in Murciano goats in Spain; a positive correlation (0.69) was found between udder volume and milk yield. In the day to day farming practice however, farmers cull any does with hanging (maximum length) udders because the latter are exposed to injuries and infections. Casu *et al.* (2010) summarized this by saying that the appraisal of the udder is a useful tool for culling decision aimed at increasing sanitary status of the flock. Animals with deep and pendulous udders are more prone to udder inflammation or mastitis. Horak and Kasing (1970) suggested that selection for certain morphological characteristics of the udder should be made since their correlation with milk production responses were favourable. Montaldo *et al.* (1993) contended that information concerning correlations

with such characteristics in goats is scarce, but knowledge about these relations is critical to design breeding programmes aimed at improving milkability and udder health in the goats. This opinion was also supported by Dzidic *et al.*, (2004) who said that knowledge of milk yield and udder conformation is necessary because a larger udder determines an increased milk production. Berry *et al.* (2002) said that a good doe should have large udder before and considerably smaller udder after milking; does with pendulous udders, which are prone to injury and infection should be avoided. Harris *et al.*, (2003) warned against mastitis, udder oedema and congestion commonly found in high producing dairy goats. In this study udder size (volume) and udder attachment (length) have been considered in correlation with the udder milk yielding capacities.

2.3.4 Age

Age structure has a direct influence on production, reproduction and genetic progress of a breeding flock (Erasmus *et al.*, 1985). In goat farming more especially Mavrogenis *et al.* (1989) wrote that udder circumference and udder depth were increasing with age, reached their maximum at 50 months (4th lactation) and declined slightly thereafter. Raats *et al.* (1983) added that maximum milk production was reached at an earlier age. Ilahi *et al.* (1999) studied milking characteristics of dairy goats and saw that age of the female, lactation stage and their interaction had a highly significant effect on milk yield. They explained this by saying that adult goats had a higher production level than the primiparous probably because of the interaction between milk secretion level and the development of the mammary gland; and also because of a possible decrease in udder wall and muscle tonicity during the productive life of a dairy goat (Mavrogenis *et al.* 1989). Akinsoyinu *et al.* (1977) studied milk yield and composition in the West African dwarf goat in Nigeria and reported that mature goat milk had a higher concentration of fat and lactose. In dairy goats, age and season of kidding are important sources of variation in milk production (Mavrogenis *et al.*, 1989). With the above in mind, goats aged 1, 2 and 4 years old have been selected in this study.

CHAPTER 3:

Materials and Methods

3.1 Introduction

The experiment was conducted at the Animal Production Institute of the Agricultural Research Council (ARC) at Irene in Pretoria where 32 does aged one to four years and including the Indigenous, British Alpines, Saanen and Toggenburg breeds (eight goats per breed) were used from parturition early in October 2008 up to a weaning of the Indigenous goats in mid-December 2008.

The experiment was a simulation of a small scale farming system where animals are raised in a semi-extension farming system with limited management intervention.

3.2 Experimentation

3.2.1 Location

The ARC – Irene experimental farm is situated between latitudes 25°53'04" and 25 °53' 10" South, and longitudes 28 °11'05" and 28 °13'39" East, on the interior plateau of South Africa known as the Highveld. The farm size is approximately 800 ha with an altitude of over 1400m above sea level and a mean annual rainfall of 708 mm. Vegetation is Acocks' Bankenveld (Veld Type 61) and is predominantly mixed grassland falling into the Grassland Biome categorization (Acocks, 1988).

3.2.2 Animals

A total of 32 goats (aged one, two and four years) which included eight British Alpines, eight Toggenburg, eight Saanen and eight Indigenous goats, were obtained for this trial. They were initially separated by breeds in different camps during the breeding season to avoid crossbreeding; mating took place naturally and thereafter all goats were mixed for spring kidding. One animal (Toggenburg N^o3) died during the trial in week four.

3.2.3 Experimental design

The experiment was a one way (feeding system) analysis of variance where eight goats were randomly selected from each breed for the measurement of 1) blood metabolites); 2) milk yield and components and 3) phenotype characteristics. This is described in Table 3.1.

Table 3.1 Diagrammatic representation of the experimental design

Breed	N	Treatments		Measurements													
		Autumn & Winter	Spring & Summer	Blood metabolites				Milk yield & components					Phenotype characteristics				
				<i>Glu</i>	<i>Cho</i>	<i>FFA</i>	<i>BUN</i>	<i>MY</i>	<i>LAC</i>	<i>Fat</i> %	<i>MP</i>	<i>MUN</i>	<i>SCC</i>	<i>A</i>	<i>Usz</i>	<i>BCS</i>	<i>Uat</i>
Ind.	8	All goats on Kikuyu +Maize Silage	Kikuyu + maize	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Tog	8		Silage + Ewe	*	*	*	*	*	*	*	*	*	*	*	*	*	*
B.A.	8		& lamb	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Snn	8		Pellets	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Legends: N = Number of goats per breed; glucose (Glu), cholesterol (Cho), free fatty acids (FFA), blood urea nitrogen (BUN); milk yield (MY), lactose (LAC), fat percentage (Fat %), milk proteins (MP), milk urea nitrogen (MUN) somatic cell count (SCC);: age (A), udder size (Usz), body condition score (BCS) and udder attachment (Uat).

Table 3.1 shows that this study measured three different sets of data which corresponded to three different experiments:

Experiment 1: Phenotype characteristics (breed, BCS, udder characteristics) and age of four different breeds of does were measured and correlated to milk yield and composition in an attempt to evaluate the relevance of using body characteristics in predicting milk yield and composition in both the indigenous and the improved dairy goats.

Experiment 2: Consisted of collecting blood samples in an attempt first, to analyse and determine the role of glucose, BUN, FFA and blood cholesterol as nutritional level indicators in the lactating goat and second, to study the correlation (if any) existing between these blood parameters and the phenotype characteristics.

Experiment 3: Related to milk characterization (milk yield and constituents: lactose, fat percentage, MUN, milk proteins and SCC) of four different breeds of goats raised under a semi-intensive production system where grazing animals were fed a minimum supplemented support aimed to meet maintenance requirement in protein and energy; the ultimate objective being to evaluate the capacity of adaptation of these different breeds of goats in the African small scale farming system.

3.2.4 Research plan

The experiment was conducted in a manner that simulated the kind of management usually found in the African small scale farming systems where little management intervention is applied and where goats are left alone to browse all year round on pasture. In this trial all the 32 goats were gathered in one camp for the night and in the morning they were released on a kikuyu pasture (“*Pennisetum clandestinum*”) for grazing. As appearing on picture 3.1 (below) a supplement made of maize silage was provided in winter while ewe and lamb pellets were added to the diet in spring during lactation.



Picture 3.1: A view of the kikuyu grazing in winter: does were supplemented with maize silage; while in spring (during lactation), a ration of ewes and lamb pellets was fed.

At the beginning of the experiment, all does were vaccinated against pulpy kidney and pasteurellosis; thereafter they were dewormed with 1ml SC injections of Moxidectin against “*Haemonchus contortus*”. From parturition blood and milk samples were

collected weekly in the morning before feeding during a period of eight weeks (mid-October to mid-December). BCS, age, udder size and udder attachment recorded at the beginning of the trial were also recorded every week (by an experienced observer) during milk and blood sampling. The diagrammatic representation of this research procedure is presented in Table 3.2.

Table 3.2. Schedule of Research plan

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Activities												
All Goats on pasture	X	X	X	X	X	X	X	X	X	X	X	X
Pregnancy					X	X	X	X	X			
Kidding										X		
Lactation										X	X	X
Winter sup..						X	X	X		X	X	X
E & L. Pellet										X	X	X
Weaning												X
Phenotype scoring										X	X	X
Body condition. Scoring										X	X	X
Milk, & blood Collection										X	X	X
Lab Analysis										X	X	X

This research plan was initially designed for three-month duration. But, with some does (mostly Indigenous) ending lactation unforeseeably at two months, the investigation period was also limited at two months. All blood and milk samples were sent to the laboratory for analysis. During week 8, a blood sample from Saanen No7 was broken and could not be analyzed. Regrettably, all week five milk samples were not analyzed on MUN and SCC. This was also the case with week eight blood samples which went to the laboratory in mid-December (year-end holiday) and could not be analyzed either. These three incidents were reflected in our records as missing data.

3.3 Data collection

3.3.1. Milk sampling

The technique used: hand milking.

Manpower: One technician + one assistant.

Materials: One bucket with lukewarm water containing 10% disinfectant

One tray containing 32 x 200 ml flasks with sealing lids

One microtablet of 0.02% bronopol (milk preservative) in each flask

Sterile needles and syringes

Cotton-wool + alcohol

1 X 500 ml measuring cylinder

1 bottle of oxytocine

1 X 20 litre steel container (for milk collection)

Procedure: The technician washed his hands in lukewarm water containing 10% disinfectant (Savlon). At the same time he very gently and very tactfully washed the doe's udder with special attention to its teats (necessary to ensure a hygienic milk collection, but also to familiarize the goat with the human's hands and physical contact). Then, the technician used alternatively his left and right hands to hold and press respectively the left and the right half udder of the doe, while at same time pulling his hands from the top of the udder to the bottom towards the teats from which milk is ejected. As the udder becomes emptier, the technician's hand pressure becomes firmer and harder to force the last drop of milk towards ejection.

During milking the assistant used his hands very tactfully (the goat has the tendency to kick anything that approaches her udder) between the doe's legs in order to collect milk that is ejected from the teats. As soon as this first session of milking is terminated, the technician washes his hands and injects a pre-arranged (by the technician) 1ml IM oxytocin into the doe which is immediately released into a separate pen where it is fed with maize silage and lambs and ewe pellets and kept away from the kids for four hours (8 am to 12 am). Milk samples for biochemical analysis is collected in a 200ml flask in the following manner: The assistant ensures himself that the milk preservative (0.02% bronopol) is effectively present in each 200 ml flask before he pours in the milk sample, seals the flask and writes on it the number of the goat whose milk has been just

collected. When all milk samples are collected, they are taken to a laboratory (Lactolab, at ARC – Irene) for milk analysis.

After four hours, a second milking session was performed. While the 8 am milking session was for quality analysis in the laboratory, the second (12 am) milking is for quantity measurement. This was done by pouring all the milk collected from one doe into the measuring cylinder on which the amount of milk collected is easily reflected. The calculation of the daily milk yield was done as follows:

Milk yield (in litres) after 4 hours x 6 = goat daily milk yield.

Milk samples were collected weekly in the morning before feeding over a period of two months.

3.3.2 Blood sampling

The technique used: Jugular venipuncture

Manpower: One technician + one assistant

Materials: Cotton wool + alcohol

Sterile needles and syringes

Heparinised test-tubes

Cooler box (in polystyrene) + ice cubes

One pair of scissors

One permanent marker

Procedure: The assistant put the goat between his knees in order to hold it firmly but gently standing on its feet; at the same time, from his hands, he held the goat's head elevated in such a way that the goat's neck could be largely accessible to the technician hands. The technician used his right hand to disinfect (with alcohol on cotton-wool) the part of the neck where he intended to introduce the needle (sometimes shaving the area was necessary when the goat was too hairy). After disinfection the technician put his left hand and maintained a gentle grip in the lower region around the neck of the goat. This light pressure results in the goat's jugular vein becoming visible. Secondly, with the left hand still on the neck of the goat, he felt through palpation with his right hand the exact size, location, and direction of the vein. Thirdly, the technician inserted slowly and very skilfully a sterile needle in the direction of the vein while respecting an angle that could

allow an easy flow of blood inside the needle; when this happens, the indication is that the vein has been punctured.

The technique of blood collection through jugular venipuncture is depicted in picture 3.2



Picture 3.2: Blood collection through jugular venipuncture in the Indigenous goat.

Then the technician attached a 10 ml heparinized test tube to the needle and ensured that 10 ml of blood was collected before he removed the needle slowly while applying cotton wool and alcohol for one minute (in order to prevent bleeding and/or infection) on the area of injection. Each test tube was marked with the corresponding goat number before it was deposited on ice cubes in the cooler box. When blood samples from all goats were collected, the cooler box was taken to the centrifuge where the test tubes were centrifuged for 10 minutes at 3000G before blood plasma (separated from cells) could be aspirated in sterile tubes, kept again on ice cube and brought to Onderstepoort (University of Pretoria) for blood glucose, blood cholesterol, BUN and FFA analysis.

3.3.3. Recording of phenotype characteristics

A new technique was developed to determine the phenotype score. The technique used: based on visual appraisal, palpation, and teeth examination.

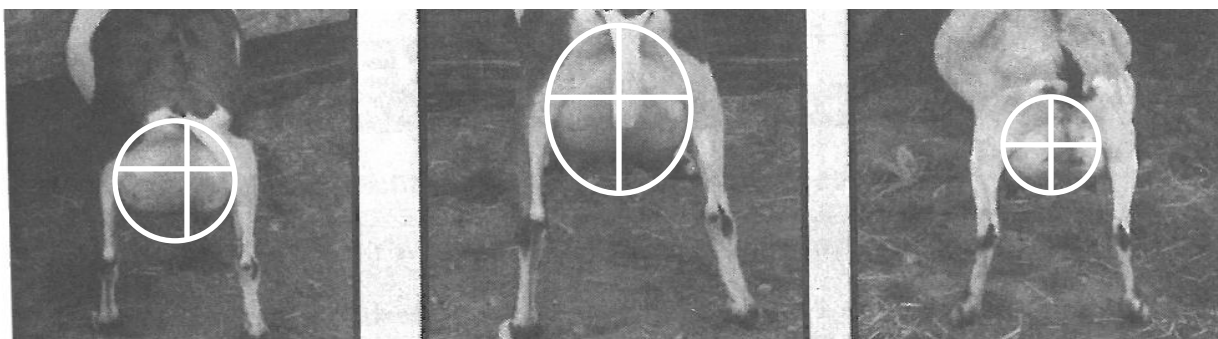
Manpower: Three assistants

Materials: writing papers, measuring tape and ball-pens

Procedure: All the goats gathered in the kraal were admitted one by one in the crush pen where assistant one proceeded with the measurement of udder size, udder attachment.

3.3.3.1 Measurement of udder size and udder attachment

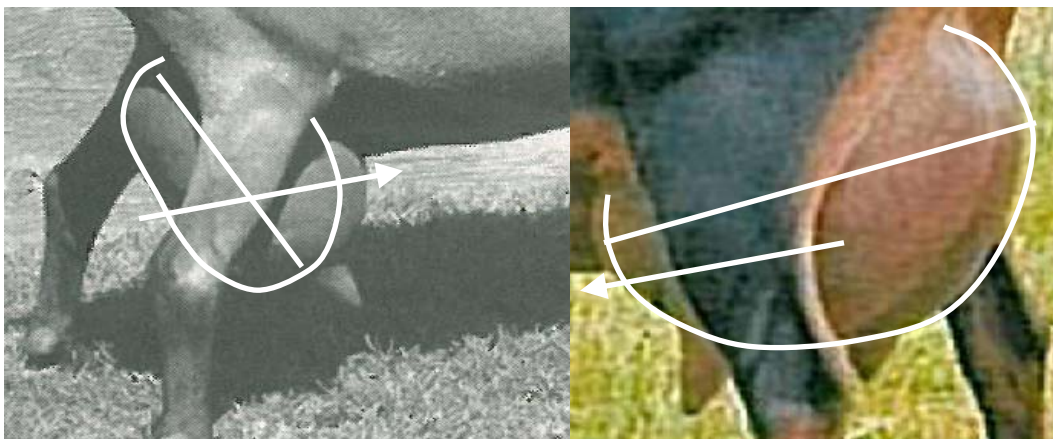
As was done by Milerski *et al.* (2006) the udder size was objectively assessed by using a measuring tape. However, because the goats could not stand still (mostly the case of the Indigenous and the Alpine breeds: when she felt a hand contact with her udder sometimes she reacted by kicking back violently), it was difficult to take an accurate measurement. The assistant did therefore take an estimated measurement. When it exceeded (or equalled) 20 centimetres it was seen as “large.” Between 20 and 15 centimetres it was “medium” and anything below 15 centimetres was seen as “low” as illustrated in picture 3.3 (below). This is illustrated in picture 3.3 (below)



Picture 3.3: Udder Size: Left = medium (± 15 cm width, ± 15 cm length) centre = large (>20 cm width, >20 cm length); and right = small (<15 cm width, <15 cm length).

Udder attachment was assessed visually, by comparing the median line of the udder to the line of the perineal region; when both lines almost paralleled the plane of the belly, the udder was recorded as “well attached”; when the median line of the udder tended to

discard itself from the belly and pointed in the direction of the soil, the udder was seen as “hanging;” this is illustrated in picture 3.4



Picture 3.4: Left: hanging udder. Right: well-attached udder

3.3.3.2. Assessment of BCS

Assessment BCS was done through palpation in accordance with the principle that, on a scale point of 1 to 5 , 1 means an extremely emaciated (cachectic) goat which is near death; and 5 an extremely obese (overly fat) goat having deep patchy fat over its entire body. The BCS examination is conducted by manual assessment of the fat cover thickness and the prominence of bone at the tail head and the loin area (Coffey *et al.*, 1999; Nix, 2004; Villaquiran *et al.*, 2007).

In practice Technician 1 first looked at the general aspect of the animal, its sternal and lumbar regions; secondly, through palpation around the shoulders, the back bones, the ribs and the hips of the goat, he evaluated the level of thickness of several muscles (*muscle semitendinosus* at the back of goat; *Muscle longissimus thoracis* around the ribs; *muscle longissimus lumborum* around the hips at the lumbar region and finally the *M longissimus dorsi* around the spine process) before he assigns a number corresponding the most approximately to the animal body condition (usually 3, 2.5, 2 or 1.5).

The ideal BCS 3 should have a non-prominent backbone with the croup as well covered as muscles which should be fully but moderately covered by fat; the spine and the transverse process should be rounded and smooth in such a way that hard pressure needs to be exerted in order to feel the ends of the transverse process. The chondrosternal

joints of the sternal region should be perceived only with a thorough fingertips palpation (Santucci *et al.*, 1991).

BCS 2 should correspond to a slightly raw-boned animal with a continuous ridge still visible on its backbone; the croup should be protuberant with a thin fat cover, a prominent spine, and a sharp transverse process whose ends should be felt easily by fingertips. About one-third to one-half of the length of the transverse process should be discernible and sternal fat still wider and thicker should be grasped and lifted by the thumb and forefinger (Villaquiran *et al.*, 2007).

BCS 1 should correspond to an extremely emaciated animal with no fat cover on a highly visible backbone showing a prominent spine; the flank should be hollow and the ribs easy to count while the croup stands out as well as a sharp transverse process (Luginbuhl *et al.*, 2009).

After the evaluation assistant 1 announced in a loud voice his decision (usually 1.5, 2, 2.5 or 3) and the number was either spontaneously recorded by the assistant 3 or discussed among the three assistants before final agreement.

Announcing loudly a decision (as done earlier while assessing udder size and udder attachment) ensured that the final decision was made on common agreement after a clear, fair and transparent evaluation.

3.3.3.3 Age determination

From assistant 1, the goat was transferred to assistant 2 who proceeded with teeth examination for the determination of age. The principle was that at one year old, one pair of central incisors is present; two years old should have two central, two medial and two lateral incisors. At three years, the table or grinding surface should be narrow, while at four years a yellow-brown ring should be seen on the white table surface, the roots of incisors being protruding. Assistant 2 (like assistant 1) announced his decision in a loud voice (usually, 1, 2 or 4 years old) and the number was immediately recorded by assistant 3, who also recorded the animal breed. The latter was not subjected to discussions since the breed of each goat (Saanen, Toggenburg, British Alpines or Indigenous) was obvious at first glance. For each goat data were carefully recorded.

3.4 Biochemical analyses.

3.4.1 Milk analysis

Milk samples were analysed on lactose, fat percentage, milk proteins, milk urea nitrogen (MUN) and somatic cell count (SCC) at Lactolab (Pty) Ltd, a SANAS accredited laboratory at the dairy building, ARC campus of Irene. At Lactolab a high-capacity Milkoscan fully automated, mid-range infrared spectrophotometer was used for the determination of fat, protein, lactose, milk urea and somatic cell count.

At the laboratory, the technician ensured that the milk samples received were in a reasonably good condition: the sample should not have started to curdle or separate, and must be free of dirt and other foreign particles. After that, the technician proceeded with pre-heating the sample in order to evenly distribute fat globules in milk. For maximum accuracy milk samples were heated to 40° C (37 to 42° C range) immediately before analysis. Overheating of samples can cause separation of fat called “oiling off”.

On the infrared spectrophotometer, a milk sample drawn up by the pipette was taken into the reaction chamber, where it was mixed with a dye solution (ethidium bromide) from the dispenser. The dye was given time to react with the DNA of each cell. The suspension was placed on a rotating wheel by means of a nozzle. The blue light caused the dye to become fluorescent, which was then counted by the detector. This counting was based on the principle that each and every single cell DNA was dyed with a specific dye, in this case ethidium bromide. The detector part of the spectrophotometer then counted the exact number of cells that passed by on the rotating disk.

3.4.1.1 Somatic cell count

In the case of SCC, the count was multiplied automatically by the working factor to give the number of somatic cells multiplied by 1000 per 1 ml milk. The IR-wavelengths used were in the 2 – 10µm range.

3.4.1.2 Lactose

In estimating the lactose content of milk the Milkoscan makes use of a compact IR (infra-red) system which is equipped with one beam, one cuvette and two mirrors. The

IR light is passed through the hydroxyl groups of lactose at approximately 9.6 μm .; the 605 milkoscan analyser uses the polarimeter as a reference method (IDF standard: 28: 1974) and the percentage weight as base unit.

3.4.1.3 Milk proteins

For the determination of protein content, the Milkoscan makes use of its compact IR (infra-red) system which is equipped with one beam, one cuvette and two mirrors. The IR light is passed through a secondary amide group of peptide bonds at approximately 6.5 μm . Milk protein is analyzed using the Kjeldjal true protein method (IDF standard 20B; 1993, part 4) with the percentage weight as a base unit.

3.4.1.4 Milk fat percentage

The fat percentage is determined with the Milkoscan making use of its compact IR (infra-red) system which is equipped with one beam, one cuvette and two mirrors. The IR light passed through the carbonyl groups of ester bonds of the glyceride at approximately 5.7 μm traditionally referred to as the “A” filter, and through the CH groups at approximately 3.5 μm traditionally referred to as the “B” filter. Milk fat is analyzed with the Milkoscan analyser calibrated against the “Rose-Gottlieb method” as described in the IDF standard 1D; the percentage weight is used as a base unit.

3.4.1.5 Milk urea nitrogen

(MUN) content is determined only one filter, all the others are used for reference. The Milkoscan makes use of its compact IR (infra-red) system which is equipped with one beam, one cuvette and two mirrors and analyses milk urea through the reference method where Foss uses the “differential pH” with the mg as a base unit.

3.4.2 Blood analyses

Blood samples were analysed for glucose, blood urea nitrogen (BUN), plasma cholesterol and plasma free fatty acids (FFA) concentrations at the Department of

Anatomy and Physiology (Faculty of Veterinary Science/Onderstepoort; University of Pretoria).

3.4.2.1 Glucose analysis

Plasma glucose concentration was determined by the use of ACE™ Glucose reagent (reagent number: NAE2-27) intended for the quantitative determination of glucose in serum using the ACE™ clinical chemistry system.

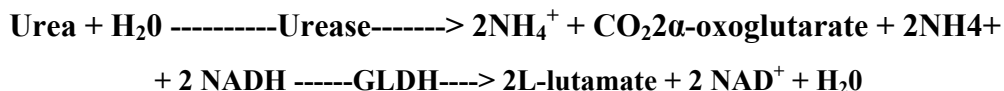
The procedure followed was:



In the ACE glucose method, glucose is determined after an enzymatic oxidation in the presence of glucose oxidase. The formed hydrogen peroxide reacts under a catalysis of peroxidase with phenol and 4-aminophenazone to form a red-violet quinoneime dye as indicator. The absorbance of the reaction is bichromatically measured at 505 nm/ 692nm.

3.4.2.2 Plasma urea concentration.

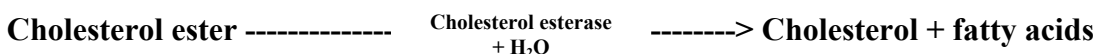
It was determined by the use of a colorimetric method whereby a NExCT™ reagent (Reagent Number: NAE5-9) is intended for the quantitative determination of urea in serum and plasma using the NExCT™ clinical chemistry system. The principle of the procedure is as follows:



The reaction rate is measured biochromatically by the ACE Alera Analyzer (Alfa Wasserman Siemens medical solutions) at 340 nm/ 647nm.

3.4.2.3 Plasma Cholesterol

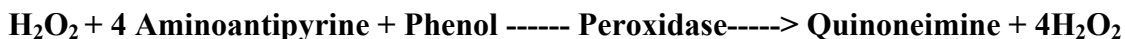
The NExCT™ Cholesterol reagent kit (Reagent number: NAE2-12) is intended for the quantitative determination of cholesterol concentration in serum using the NExCT™ clinical chemistry system. The principle of this procedure is as follows:



The cholesterol liberated by the esterase, plus any free cholesterol originally present in the plasma are both oxidized by cholesterol oxidase:



The liberated peroxide reacts with phenol and 4-aminoantipyrine in a peroxide catalyzed reaction to form a quinoneimine dye, which absorbs at 500nm:



The change in absorbance is measured bichromatically at 505nm/692nm and is directly proportional to the amount of cholesterol present in the sample.

3.4.2.4. Plasma FFA: free fatty acids concentration was determined by an enzymatic colorimetric method based on the method of Falholt combined with the modified colorimetric technique of Novak. This method is based on the extraction of phosphate buffered plasma with a chloroform heptane-methanol mixture, formation of the cobalt complex and on the subsequent determination of metal with 1-nitroso-2-naphtol. The absorbance was read after 30 minutes in a spectrophotometer at either 500nm or 450 nm (De Villiers *et al.*, 1997)

3.4.3 Feed analyses

Feed analysis was performed at Nutrilab (University of Pretoria-Department of Animal and Wildlife Sciences). Kikuyu grass (*Pennisetum clandestinum*) and maize silage were analysed for GE, CP, ME, Ca and P. The ewes and lamb pellets was not analysed because the label provided by the manufacturer (Epol) was indicating the pellet composition on its contents. Results on feed analyses are represented in Table 3.3.

Table 3.3: Chemical composition of samples of kikuyu (*Pennisetum Clandestinum*) and ewes and lamb pellets fed to does from week two to week eight

Forage	DM ⁽¹⁾ g/100g	N ⁽²⁾ g/100g	CP ⁽³⁾ g/100g	GE ⁽⁴⁾ MJ/Kg	Ca ⁽⁵⁾ g/100g	P ⁽⁶⁾ g/100g	Ca : P
Kikuyu	25	3.6	22.3	6.8	0.472	0.316	1.5 : 1
Maize silage	45	1.5	7.2	11.8	0.194	0.171	1.1 : 1
E&L pellets ⁽⁷⁾	88		13				

Legends: Superscripts (1) Dry Matter; (2) Nitrogen; (3) Crude Protein (4) Gross Energy; (5) Ca: Calcium; (6) P: Phosphate; (7) Ewe and lamb pellets (commercial product) composition as labelled : Fat 250g/kg; Urea : 100g/kg; Vitamin A: 5g/kg.

3.4.3.1 Gross energy (GE)

The determination of Gross Energy in food was done with the Method reference MC-100 Modular calorimeter. The procedure consisted first in ensuring that the water tap connected to the chamber is open and the computer is on, before placing the sample inside the chamber; secondly, the technician opened the oxygen bottle and switched the chamber on. When the computer indicated that the chamber was ready, the technician entered the sample ID number, the sample mass and pressed “Enter”. The calorimeter run for approximately 5 minutes to ignite and burn the sample; during this time it performs the following: 1) Testing temperature 2) pre-period 1 and 2 3) Bomb firing, 4) main period 5). Cooling and washing the bomb and then the result appears on the screen of the computer.

3.4.3.2 Crude protein (CP)

CP in animal feed was analysed after Dumas method (AOAC Official Method 968,06, 2002). The principle is that N₂ freed by pyrolysis and subsequent combustions, is swept by the CO₂ carrier into a nitrometer. CO₂ is absorbed in KOH and volume residual N₂ is measured and converted to equivalent protein by a numerical factor. The apparatus and reagents involved are the N₂ analyzer and its accessories, the balance accurate to 0,01mg and a barometer Hg type readable to 0.1mm. The instrument can be operated only in accordance with the instructions of the manufacturer; in this case: Coleman Model 29A Nitrogen Analyzer for which the operating directions D-360B are obtainable from Coleman Cat. 29-904)

3.4.3.3 Calcium (Ca)

Ca determination was performed in accordance with the AOAC official method 927,02 2002 applicable to animal feeds only. It is a Dry ash method which makes use of 2g finely ground test portion into SiO₂ and ignited in the furnace to C-free ash. Later the residue is combined in consecutive procedures of mixture involving chemical products like HCl, HNO₃ NH₄OH, (NH₄)₂C₂O₄ before heating to 70°C and titrate with 0.02M KMNO₄. The presence of paper may cause colour to fade and correction for blank must therefore be done before calculating the percentage of Ca. This procedure is referenced JAOAC 10, 177 (1927); 19, 93.574 (1936); 28, 80 (1945) CAS7440-70-2 (Calcium).

3.4.3.4 Phosphorus (P)

P determination was done by means of the AOAC Official Method 965.17 applicable in animal feed and pet food. It is a photometric method making use of a spectrophotometer with the molybdovanadate as a reagent and a phosphorus standard solution made of a stock solution (KH_2PO_4 in H_2O) mixed to a working solution. After the preparation of the standard curve the determination is made by reading the percentage titration at 400nm. This method of analysis, revised in March 1996, is referenced JAOAC 48, 654 (1965); 59, 937 (1976) CAS- 7723-14-0 (phosphorus).

3.5. Statistical analyses.

Experiment 1 and 2 analysis of variance (ANOVA) was used to test for differences between 4 breeds of goats, 3 ages, 3 body condition scores, 3 udder sizes and 3 udder attachments. Data were acceptably normal with the homogeneous treatment variances but milk characteristics (milk fat percentage, lactose, milk proteins, MUN and SCC) were logged to stabilise treatment variances. Treatment means were separated using the Bonferroni adjustment for multiple comparison SPSS at 5% level of significance (Snedecor & Cochran, 1980).

Experiment 3 analysis of variance (ANOVA) for unbalanced data was used to test for differences between eight goats (Indigenous) and 24 dairy goats (eight times three different breeds of goat) on milk yield and composition. The data were acceptably normal with homogeneous treatment variances, except for CCN which had to be transformed to \log_{10} to stabilize treatment variances. Testing was done at the 5% level. Treatment means were separated using Fisher's protected t-test least significant difference (LSD) at the 5% level of significance (Snedecor & Cochran, 1980). Data were analysed using the statistical program GenStat® (2005).

The study of correlations was done with SAS statistical software version 9.2 (SAS, 1999), while the statistical multiple regression equations analysis was done on phenotype parameters using the stepwise procedure (at alpha procedure entry 0.25 in Minitab statistical software 14).

CHAPTER 4:

Results and discussion: Effect of goat breed on milk yield and components

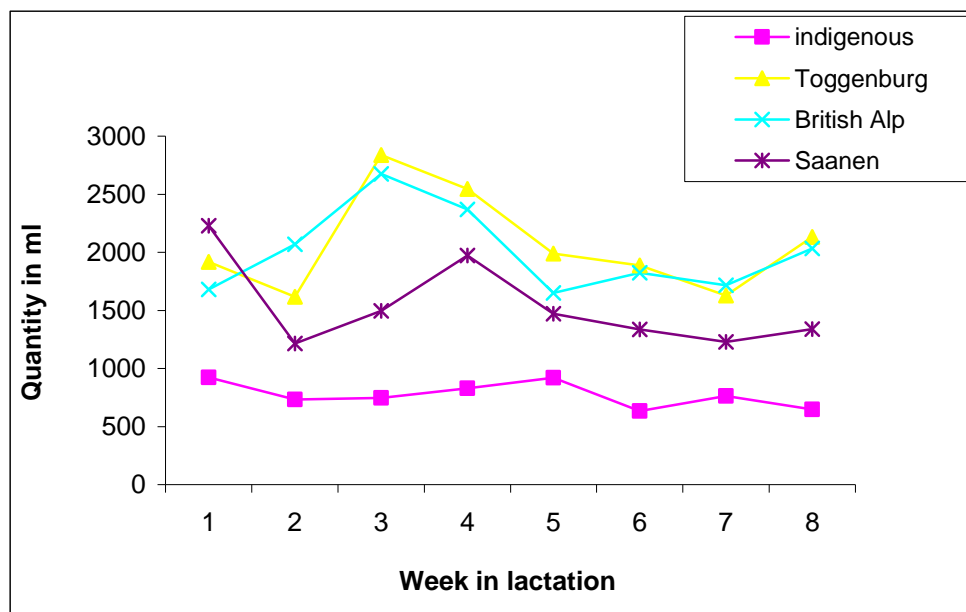
4.1. Milk Yield

Average values obtained for milk yield are presented in Table 4.1 and the trends for different breeds are illustrated in Graph 4.1.

Table 4.1: Mean milk yield (\pm SD) in ml from Indigenous and Dairy does during the first eight weeks lactation

Variables	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Indigen.	924 \pm 270.9 ^a	733.7 \pm 321.8 ^a	746 \pm 260.6 ^a	829.5 \pm 315.5 ^a	921 \pm 313.5 ^a	634.5 \pm 353.6 ^a	762.5 \pm 361.9 ^a	648 \pm 213.2 ^a
Dairy	1899.5 \pm 656.1 ^b	1769.5 \pm 825.5 ^b	2338.0 \pm 915.5 ^b	2285.2 \pm 724.1 ^b	2698 \pm 5087.3 ^b	1686 \pm 706.5 ^b	1536.7 \pm 432.5 ^b	1857 \pm 672.0 ^b
P value	p<0.001	p< 0.001	p< 0.001	p< 0.001	p< 0.001	p<0.001	p< 0.001	p<0.001

Means per same column with different superscript letters (^a^b) significantly ($p \leq 0.05$) differed



Graph 4.1: Mean milk yield of Indigenous and dairy does during the first eight weeks of lactation.

Results on milk yield found in this study are consistent with those from Shamay *et al.* (2000); lower than those found by Fernandez *et al.* (2008) and higher than those reported by Makun *et al.* (2008). These differences are probably due to the fact that milk yield is subject to much variation both between and within breeds (Richardson, 2009). In Table 4.1 and Graph 4.1, it can be seen that milk yield from dairy does (Saanen, Toggenburg and the British Alpines) was higher ($p < 0.001$) than the Indigenous milk yield during the entire period of study. The dairy breed superiority in milk yield is general knowledge in animal science. Dairy breeds have long been selected for milk production; their metabolism is entirely under a homeorrhetic control whereby, at the onset of lactation, many – perhaps even most – maternal tissues undergo further adaptations to support lactation through the mobilization of body resources at the expenses of other processes for the solely objective to support the ongoing galactopoiesis (Bauman *et al.*, 2008). Moreover, the milk yield of indigenous goats in the tropics is generally low; probably because these goats are meat or dual purpose types, while dairy breeds of goat are, as said earlier, highly selected for milk production (Akinsoyinu *et al.*, 1977). This was verified by Katanos *et al.* (2005) who investigated the partitioning, yield and milk constituents of milk in some imported dairy goats and some crosses between them and the local goats. Results showed that daily milk yield was higher in the Saanen and the Saanen cross Alpines compared to the Saanen cross local and to the local breed of goats. They concluded that the milk yielding of the Saanen and the Alpine genotypes was superior. This is supporting the results found in this study (in Graph 4.1) where the Toggenburg, Saanen and Alpines milk yield is higher than the indigenous does milk yield. In Graph 4.1 one can also notice in week one a decline in the Saanen, the Alpines and the indigenous does' milk yield. A decline that was associated with the BCS decline (from 3.0 to 2.5 and 2.0) in dairy breed as is shown in Table 4.2 below.

Table 4.2: BCS in all goats during eight weeks of lactation (n = 8)

Weeks/lactation	0	1	2	3	4	5	6	7	8
Breeds									
Indigenous	3	3	3	3	3	3	3	3	3
Toggenburg	3	2.5	2	2.5	2	2	2.5	2	2.5
Brit. Alp.	3	2.5	2.5	2	2	2	2	2	2
Saanen	2.5	2	2	1.5	1.5	1.5	2	1.5	2

This decline suggests that, in goat dairy breeds body reserves were massively mobilized to support the high milk production. In an attempt to correct the declining BCS, farm management supplied the does with an *ad libitum* provision of ewes and lamb pellets. The general decline in milk yield during the first week (Graph 4.1) deserves attention since the classic lactation curve in goat milk yield usually displays the highest milk yield in early lactation (see Graph 1.1) before a gradual decline towards mid-lactation; this is not what appeared in Graph 4.1, where it is observed that, except from the British Alpines, milk yield dropped in all does during the first week. A possible explanation for this general milk yield decline could be that, in that year (2008), the first rain fell only on the 27, 28 and 29 September, pouring 35.4mm of water over the experimental farm (25mm are the minimum required for grass to start re-growth); as a consequence, the mid-October kidding, two weeks later, coincided with the emergence of new shoots and shrubs on the good early spring pasture which, however, was inadequate to compensate for the long-lasting negative energy balance under which the goats were raised. It is indeed well documented (Church, 1979; Perry, 1980; Meissner, 1994) that during early lactation, post-parturient ruminants are always in a negative energy balance because their reduced appetite does not allow them to match the highly lactation increased energy demand. Under such circumstances Rapetti *et al.* (2005) suggested that good forage (hay) does enhance milk performance, but low quality forage, even if highland fresh grass is available, cannot guarantee good quantitative and qualitative milk performance. We therefore anticipate that the early lactation increased energy demand exacerbated by the poor nutritional supply from early spring grazing, resulted in the decline of milk yield, observed in all does week one milk yield performance seen in Graph 4.1.

As for the indigenous goats, their milk production remained significantly ($p < 0.001$) lower, with no significant change in their BCS which still averaged 3.0. This can be explained by the fact that Indigenous goats are not “milk making machines”. Most milk yields of the Indigenous goats in the tropics are generally low (Akinsoyinu *et al.*, 1977). The Indigenous goats are dual or meat type animals; their metabolism responds to a central homeostatic control where resource partitioning prioritizes the maintenance of a

constant internal equilibrium. This homeostasis is reflected firstly by stability of BCS in indigenous does at three; secondly by stability in milk yield performance seen in Graph 4.1 (in contrast to the erratic milk yield performance of dairy breeds).

Results as seen in Graph 4.1 also suggest that within dairy breeds milk yield performance was not similar between does' breeds. From the moment the concentrate supplement was fed (week two), milk yield increased substantially in all dairy breeds; and the tendency for the Toggenburg (nicknamed "Guernsey goat") to produce more milk than the Saanen and British Alpines became evident (week three).

The supplied ewes and lamb pellets contained 130g/kg CP; this amount of CP has the potential to increase milk yield of lactating goats (Morand-Fehr *et al.*, 1980). Other authors (Landau, 1993; Vadhanabhuti *et al.*, 1995; Mackle *et al.*, 1999; Salim *et al.*, 2002; Min *et al.*, 2005; Hart, *et al.*, 2005; Zucali *et al.*, 2007; Sahlu *et al.*, 2007; Gomes-Cortes *et al.*, 2009; Kamal *et al.*, 2010) also support the concept that concentrate supplementation indeed affects milk yield and constituents in lactating does. This explains why milk yield increased in all does of dairy breed in week two.

However, milk production depends on many factors and not solely on feeding (Raynal-Ljutovac *et al.*, 2008; Pulina, 2002). Several factors in production and feeding and their interactions can influence milk yield and constituents (Morand-Fehr *et al.*, 2007). This was evidenced in this study by the case of the British Alpine (in Graph 4.1 week one); while milk yields from all dairy breeds of goat dropped in week two, the Alpine milk yield, in contrast, increased significantly at this specific moment. The Alpine's milking capability did not seem to be affected by the poor nutritional supply from pasture. Their production record remained high for the rest of the investigation period. Min *et al.* (2005), studying the milk yield performance of Alpine dairy does, reported that does grazing on forage alone produced milk inexpensively, while other high-producing dairy goats needed moderate levels of concentrate supplementation for economic success. The latter supports the higher milk yield performance of Alpine does recorded in this study.

4.2. Milk Constituents

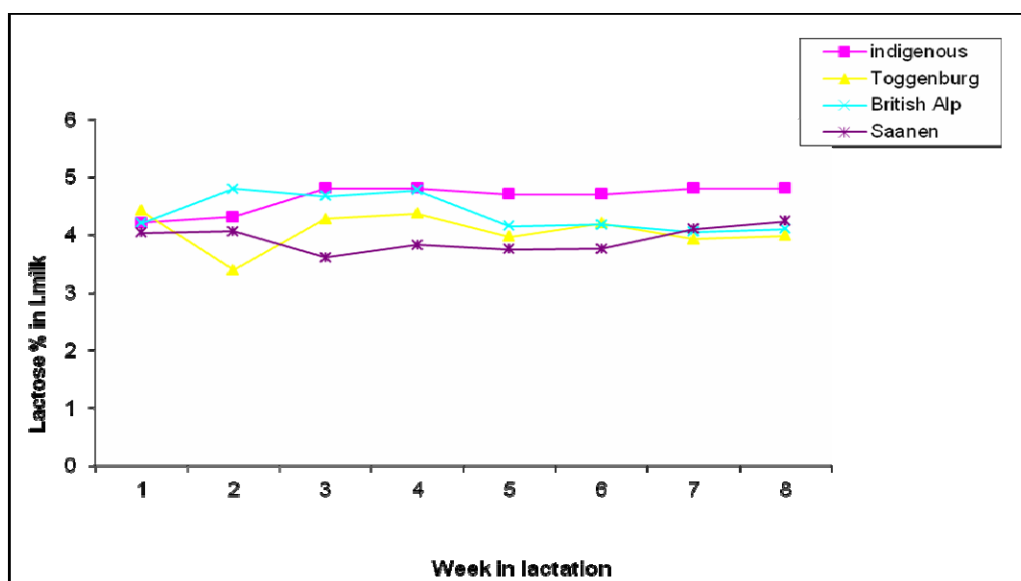
4.2.1 Lactose concentrations

Results on lactose content of goat milk found in this study are presented in Table 4.3 and Graph 4.2. Lactose is the most stable constituent of goat milk (Lu, 1993; Torii *et al.*, 2004; Katanos *et al.*, 2005; Contreras *et al.*, 2009; Fernandez *et al.*, 2008; Raynal-Ljutovac *et al.*, 2008). The lactose percentage recorded in this study display a general tendency for stability; this concurs with Voutsinas *et al.* (1990) who claimed that lactose was fairly constant with no substantial changes over lactation period.

Table 4.3: Difference in mean lactose concentrations percentage (\pm SD) in milk from Indigenous and dairy does during the first eight weeks of lactation

Variables	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8
Indigenous	4.2 \pm 0.93	4.3 \pm 0.84	4.8 \pm 1.04	4.8 \pm 0.62 ^a	4.7 \pm 0.65 ^a	4.7 \pm 0.44 ^a	4.8 \pm 0.34 ^a	4.8 \pm 0.34 ^a
Dairy Breeds	4.2 \pm 0.57	4.1 \pm 0.24	4.3 \pm 1.06	3.9 \pm 0.84 ^b	4.0 \pm 1.06 ^b	4.0 \pm 0.72 ^b	4.1 \pm 0.78 ^b	4.1 \pm 0.78 ^b
p-value	0.487	0.620	0.134	p<0.001	p<0.01	p<0.005	p<0.001	p<0.001

Mean per column followed by different superscript (^a^b) letters differed significantly ($p \leq 0.001$)



Graph 4.2: Lactose percentage in milk from Indigenous and dairy breeds during the first eight weeks of lactation

In dairy goats a decrease in milk lactose concentration may be indicative of stress and/or infection in the mammary gland (Merin *et al.*, 2004; Leitner *et al.*, 2004; Bernacka, 2007; Kifaro *et al.*, 2009). An increase in milk lactose content in goat milk may suggest a decrease in feed intake (Dahlborn *et al.*, 1987; Min *et al.*, 2005;) or severe heat exposure (Sano *et al.*, 1985) which may also results in a decreased feed intake.

Graph 4.2 and Table 4.3 reveal that lactose percentage in milk from dairy breeds remained below 4.7 especially in week two and in week five. This in milk lactose production of goats could have been seen as an indication of stress or at least as an on-going crisis in the dairy does metabolism; especially since at the same time, lactose concentration displayed a remarkable stability in the indigenous does with a significant ($p < 0.001$) difference in lactose concentration (from week four to week eight). This superiority in lactose percentage in indigenous does may derive from the fact that the Indigenous breed produced the lowest amount of milk. Low-yielding goats tend to have a high blood glucose concentration but a poorer uptake for glucose than the high producing goats (Chang *et al.*, 1996). Graph 5.1 indeed shows that the Indigenous does had a higher glucose concentration than the lactating dairy does. Since glucose is the unique precursor to lactose, one can understand why under this report the indigenous goats had higher lactose than all the dairy does.

4.2.2 Concentrations of milk proteins

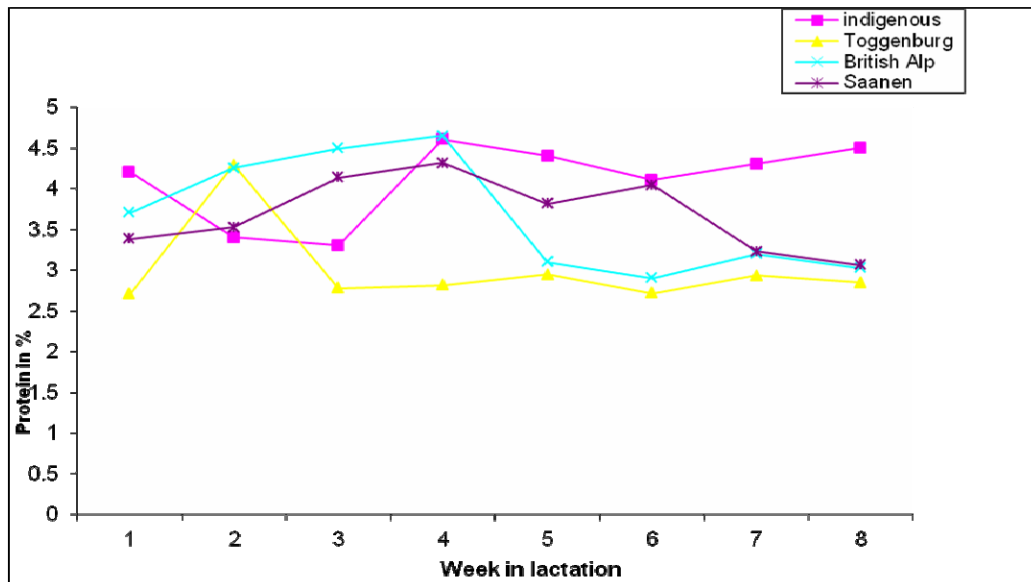
Results on milk proteins are presented in Table 4.4 and Graph 4.3.

Table 4.4: Difference in mean concentrations of proteins percentage (\pm SD) in milk from Indigenous and dairy does during the first eight weeks of lactation

Variables	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Indigenous	4.2 $\pm 1.25^a$	3.4 ± 1.80	3.3 ± 0.89	4.6 ± 1.25	4.4 $\pm 0.76^a$	4.1 $\pm 1.60^a$	4.3 $\pm 0.94^a$	4.5 $\pm 0.91^a$
Dairy Breeds	3.2 $\pm 0.69^b$	4.1 ± 0.75	3.8 ± 1.28	4.0 ± 1.41	3.3 ^b ± 0.90	3.3 ^b ± 1.36	3.1 $\pm 0.61^b$	3.0 $\pm 0.44^b$
p-value	$p < 0.01$	0.163	0.898	0.246	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$

Means per column followed by different superscripts (^{a,b}) were significantly ($p \leq 0.001$) different

Milk protein values found in this study are comparable and fall into the range of those reported by Greyling *et al.* (2004); Torii *et al.* (2004); Katanos *et al.* (2005); Karzis *et al.* (2007); Casamassima *et al.* (2007); Rovai *et al.* (2007); Fernandez *et al.* (2008); Raynal-Ljutovac *et al.* (2008) and Contreras *et al.* (2009).



Graph 4.3: Concentration of proteins in milk from Indigenous and dairy breeds during the first eight weeks of lactation.

In Table 4.4 and in Graph 4.3, it appears that the indigenous milk proteins concentration is significantly ($p < 0.01$) higher than the dairy breeds milk; especially in week one and from week four to week eight. In contrast, the Toggenburg, which produced the highest milk yield (Graph 4.1), show the lowest milk protein concentration in Graph 4.3. These results are in accordance with those of Zumbo *et al.* (2007) who studied the quantitative and qualitative milk characteristics of the “Rossa mediterranea” goats. Their results showed a negative correlation ($r = -0.18$; $p < 0.05$) between quantity and quality in does milk. Many other authors (Rabasco *et al.*, 1993; Landau *et al.*, 1993; Todaro *et al.*, 2005) have reported and supported this negative genetic correlation existing between quantity of milk and 1) proteins and 2) fat contents of milk. Body reserves are made of fat and muscle body content (Vera-Avila *et al.* 2009). It is therefore not surprising that the indigenous does, the low-yielding breed of the trial displayed a

highest fat and proteins percentage among the lactating does. Mba *et al.* (1975) working on milk composition of West African Dwarf, Red Sokoto and Saanen goats observed that milk of the West African Dwarf contained more butter fat, more protein and more lactose than milk of the Red Sokoto and the Saanen..This explains why in this study milk from Indigenous was higher in milk protein than milk from the dairy breeds.

In Graph 4.3 the British Alpine’s performance in protein concentrations is once again outstanding during the first four weeks of lactation. The Alpine’s exceptional performance was already observed on milk yield (Graph 4.1) and milk lactose (Graph 4.2). The Alpine dairy goats grazing on forage alone can produce milk inexpensively (Min *et al.*, 2005). However, from week four, the Alpine’s milk protein concentration declined drastically (supplanted by the indigenous doe’s milk proteins); this probably happened as a late response to the “dilution effect”: the negative correlation existing between milk yield and milk protein concentrations reported by Zumbo *et al.* (2007).

4.2.3 Milk fat concentrations

Results on milk fat concentrations are presented in Table 4.5 (below) and Graph 4.4 (next page).

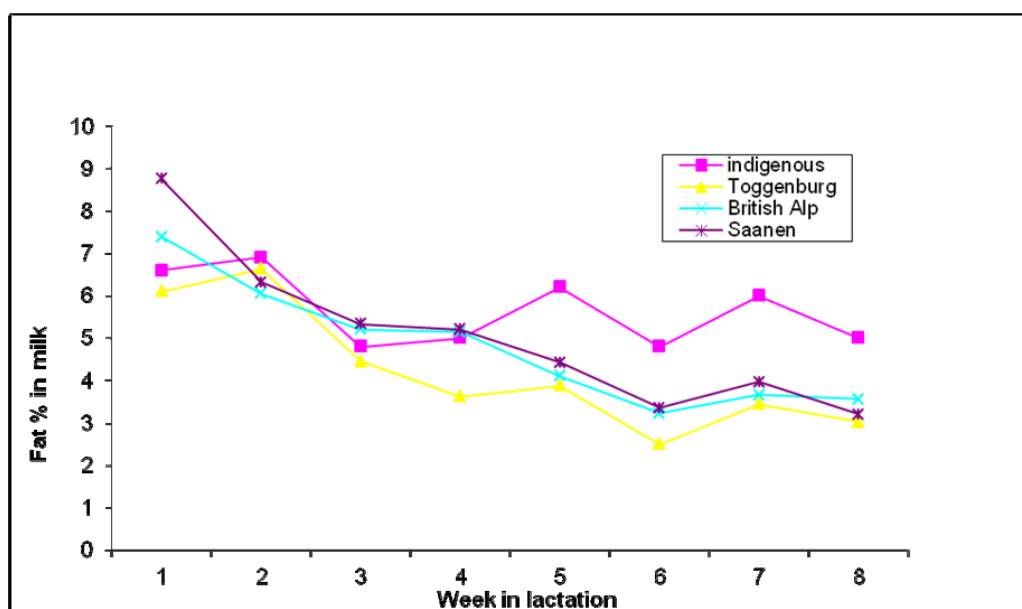
Table 4.5: Difference in mean concentration of fat percentage in milk (\pm SD) from Indigenous and dairy does during the first eight weeks of lactation

Variables	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Indigenous	6.6 ± 4.38	6.9 ± 1.56	4.8 ± 2.46	5.0 ± 1.58	6.2 $\pm 4.62^a$	4.8 $\pm 2.84^a$	6.0 $\pm 2.96^a$	5.0 $\pm 3.07^a$
Dairy Breeds	8.0 ± 4.02	6.9 ± 2.12	4.9 ± 2.18	4.6 ± 2.42	3.9 $\pm 1.60^b$	3.3 $\pm 2.25^b$	3.5 $\pm 0.91^b$	3.2 $\pm 0.98^b$
p-value	0.220	0.526	0.855	0.513	p< 0.001	p< 0.001	p< 0.001	p< 0.001

Means per same column with different superscript letters (^a^b) significantly (p \leq 0.001) differed

Values found in this study are within the range of those reported by Chilliard *et al.* (2003); Greyling *et al.* (2004); Katanos *et al.*(2005); Nudda *et al.* (2006); Alvarez *et al.* (2007); Bouattour *et al.* (2008); Fernandez *et al.*, (2008); and Contreras *et al.* (2009).

In Graph 4.4 there is a general tendency for milk fat decline from week one to week eight. Mioc *et al.* (2007) observed a decrease in short-chained fatty acids concentration with the advancing lactation. Chilliard *et al.* (2003) explained this decline by at least two phenomena: firstly, the “dilution effect” whereby a low fat concentration coincides with an increased milk volume; secondly by a decreased fat mobilization which decreased the plasma NEFA availability, especially in C18:0 and C18:1, for mammary lipid synthesis. Milk fat content and proportion of acids with 18 carbon atoms are indicators of lipomobilization (Santucci *et al.*, 1991).



Graph 4.4: Milk fat percentage between Indigenous and dairy breeds during the first eight weeks of lactation.

Morand-Fehr *et al.* (2007) reported that milk fat content was stable at the first stage of lactation and decreased later under the effect of dilution. This opinion was already expressed by Zeng *et al.* (1997) and by Chilliard *et al.* (2003) who all indicated that, in goats, milk fat content is high after parturition and decreases during the major part of lactation. This decline was also observed by Bouattour *et al.* (2008) who explained that, the response of milk fat secretion is usually higher during early lactation because *de novo* lipogenesis is usually more active after peak lactation than before it; after peak

lactation dietary fatty acids would probably be partitioned more to the adipose tissues synthesis.

Fernandez *et al.* (2008) stated that in general, fat and protein content were higher at the beginning than at the end of lactation when milk volume decreased. Those explanations clarify the general milk fat concentrations decline seen in all does in this study. Indigenous goat milk fat concentration was significantly ($p < 0.001$) higher as compared to the dairy breed milk fat (especially from week five to week eight). This kind of results was observed by Mba *et al.* (1975) who found an higher milk fat in the dwarf African than in the Red Sokoto and Saanen. Their conclusion was that milk from dairy breeds imported in tropical environment tended to fall. The explanation given was that high temperatures depress the production of acetic acid in the rumen; and a low level of ruminal acetic acid could in turn depress butterfat production.

Notwithstanding the influence of other related factors such as breed, nutrition and climate, production level is the factor that had the strongest influence on milk constituents, especially on fat percentage (Iloje *et al.*, 1981; Todaro *et al.*, 2005; Fernandez *et al.*, 2008). In this study, it has been observed that goats with lower milk production level had a higher fat percentage: the indigenous does displayed the lowest milk yield (Graph 4.1), but the highest milk protein concentration (graph 4.3) and the highest fat content of milk (Graph 4.4). At the same time the Toggenburg produced the highest milk yield (Graph 4.1) but the lowest milk proteins (Graph 4.3) associated to the lowest milk fat concentration (Figure 4.4) especially from week two to week six. These results were earlier reported by Zygoiannis *et al.* (1986) and also by Berhane *et al.* (2006) who all observed a significant negative correlation existing between milk yield and concentrations of fat and proteins; a negative correlation which is coming as a support to the “Dilution effect” reported by Zumbo and Di Rosa (2007) (Table 4.4 and Graph 4.3)

Interestingly, in Table 4.5 and Graph 4.4, there is a tendency for stability in the Indigenous does’ milk-fat concentration especially from week four to week eight. This stability in the Indigenous goat’s performance has been earlier discussed with the goats milk yield (Figure 4.1), the Indigenous does’ lactose content of milk (Graph 4.2) and the Indigenous does’ protein concentration in milk (Graph 4.3). Stability in the Indigenous

goat performance has a reference in the role of the central homeostatic control upon the indigenous does' general metabolism.

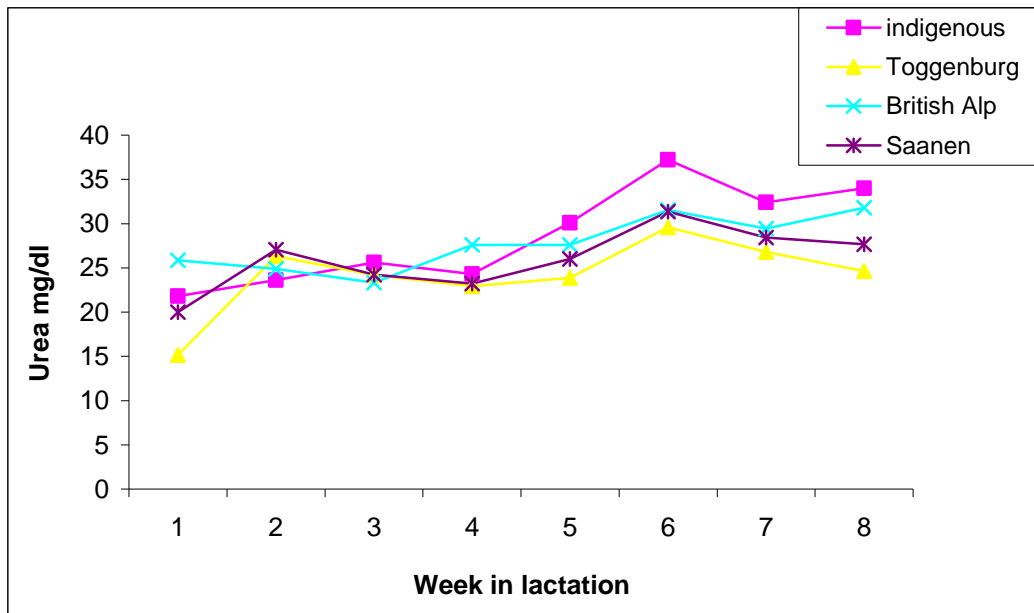
4.2.4 Milk urea nitrogen (MUN) concentrations

Results on goat MUN concentrations are displayed in Table 4.6 and Graph 4.5. Those results are in the range of those reported by Bava *et al.* (2001) and Bonanno *et al.* (2008).

Table 4.6: Mean MUN concentration (\pm SD) in milk from Indigenous and Dairy does during the first eight weeks of lactation

Variables	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Indigenous	21.8 \pm 8.86	23.6 \pm 8.50	25.6 \pm 11.56	24.3 \pm 11.50	-	37.2 \pm 11.13	32.4 \pm 7.34	34.0 \pm 9.91
Dairy Breeds	20.4 \pm 11.17	26.7 \pm 6.86	24.2 \pm 5.19	23.5 \pm 7.18	-	31.2 \pm 10.40	28.4 \pm 7.87	28.2 \pm 9.34
p-value	0.105	0.690	0.115	0.668	-	0.432	0.266	0.360

No significant difference was found between means



Graph 4.5: MUN concentration in milk from Indigenous and Dairy does in the first eight weeks of lactation.

In Graph 4.5 all goats MUN are gradually increasing from week one to week eight. There is a high correlation between blood urea nitrogen (BUN) and MUN (Oltner *et al.*, 1983; Khaled *et al.*, 1999) which is simply justified by the fact that BUN is isotonic to MUN (Pulina *et al.*, 2002; Sherwood *et al.*, 2005; Bonanno *et al.*, 2008). In this study, results on BUN are presented in Graph 5.2. When comparing Graph 4.5 to Graph 5.2, there is a striking resemblance between BUN and MUN concentrations in week three. In both cases there is a clear increase from week three to six. The similarity found on both tendencies is lending support to the existence of a positive correlation existing between milk yield and MUN (Todaro *et al.*, 2005). Observing performance of all does MUN concentrations on week one, there is an increase in the Toggenburg and the Saanen MUN, which is in contrast firstly with the British Alpines and the indigenous does week one MUN stability and secondly, with all does week one BUN decrease (as it appears later on Graph 5.2).

These results can be explained by the fact that in early lactating goats nutrients partitioning do not depend on dietary intake, which was low as attested by all does week one decrease in both Milk yield (Graph 4.1) and BUN (Graph 5.2). This may support what was hypothesized earlier: During lactation (especially in early lactation) goat dairy breeds physiology responded to a homeorrhetic central mechanism which resulted in the mobilization of body reserves (whence the subsequent BCS decline associated to a week one MUN increase) in order to support milk yield. These changes took place while the indigenous does' week one MUN remained unchanged proving their strong dependency upon the homeostasis central command. As for the Alpines does, whose performance did not depend on the rangeland capacity (early spring growing kikuyu), they displayed an outstanding performance: maintaining stability in week one MUN and increasing week one milk yield (Graph 4.1) in an environment where food inadequacy dictated a decline in all doe's milk yield (Graph 4.1)

On Graph 4.5 there is again a tendency for the Indigenous does' MUN concentration to be higher from week four onwards. A general elevation in MUN is, in dairy farm practice, an indication that urea is either misused (excess in CP dietary source) or wasted metabolically (on-going ureogenesis) (Bonanno *et al.*, 2008). In the case of the Indigenous does, the elevation in MUN seems to be an indication of an on-going

ureogenesis process subsequent to the advancing lactation. This interpretation is based on the following facts: Firstly, ureogenesis and gluconeogenesis are linked processes (Bergman, 1983; Belyea *et al.*, 1990). In this study the increase in the Indigenous BUN concentration (Graph 5.2, week six to seven) was followed (and attested) by an increased Indigenous blood glucose concentration in week seven (Graph 5.1.). Secondly, BUN being isotonic to MUN, the latter was also elevated as from six onwards. Under such circumstances the indigenous BCS was also expected to decline but somehow (homeostasis?) the Indigenous BCS remained unchanged.

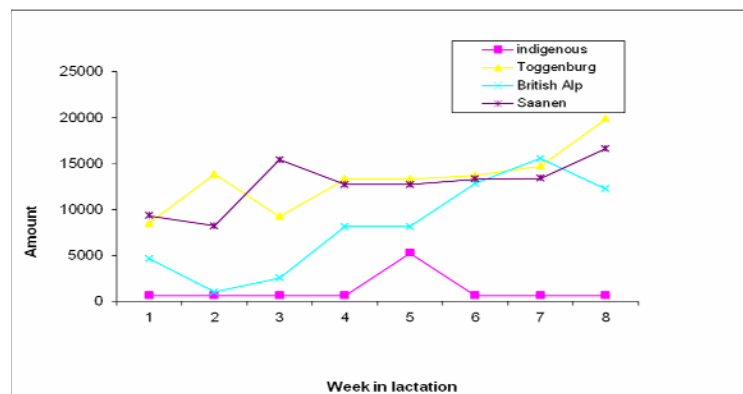
4.2.5 Milk somatic cell count

Results on SCC concentrations are presented on Table 4.7 and on Graph 4.6

Table 4.7: Difference in mean (x1000) Somatic cell count (SCC) concentration (\pm SD) between milk from Indigenous and Dairy does during the first eight weeks of lactation

Variables	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Indigenous	626.8 \pm 493.8 ^a	627.8 \pm 10080 ^a	628.8 \pm 11485	629.8 \pm 8847	-	631.8 \pm 1912 ^a	632.8 1398 ^a	633.8 \pm 1658.3 ^a
Dairy Breeds	20649 \pm 8754 ^b	17577 \pm 8349 ^b	217075 \pm 9778	236422 \pm 9695	-	30509 \pm 7557 ^b	32083 9272 ^b	35334 \pm 8957 ^b
p-value	p<0.001	p<0.001	0.947	0.021	-	p<0.001	p<0.001	p<0.001

Means per column followed by different superscripts (^{a,b}) were significantly ($p \leq 0,001$) different



Graph 4.6: Mean SCC (x1000) concentration in milk from the Indigenous and Dairy breeds during the first eight weeks of lactation.

Values found in this study are comparable to those reported by Zeng *et al.* (1995), Zeng *et al.* (1997) and Paape *et al.* (2007). At the first glance on Graph 4.6, the general impression reflects an erratic performance in all does SCC. These disparities were already been observed by Fernandez *et al.* (2008) who worked on SCC and quality of goat milk in Mexico and concluded that there were important individual differences among doe's milk SCC.

Haenlein (2002) studied the relationship between SCC in does to mastitis and productivity; he found that milk samples SCC differed significantly before, during and after milking. Earlier studies conducted by Zeng *et al.*, (1996) on the effect of breed and milking method on SCC of goat milk indicated significant variations among goat herds. Zeng *et al.* (1997) indicated that SCC and daily milk yield varied throughout lactation depending on numerous factors such as morning versus evening milkings, stage of lactation, parity and breed. Mena *et al.* (1999) studied the SCC in all farms having more than 50 goats in Seville (Spain); significant differences ($p < 0.001$) were found according to herd size: 1,072,000 cells/ml for farms with few numbers of animals and 2,209,000 for larger herds.

Graph 4.6 shows a significant difference ($p < 0.001$) between the Indigenous doe's milk SCC and the dairy goats milk SCC (especially from weeks one to three; and from weeks five to eight). Among the dairy breeds however, the Alpines tended to have the less SCC up to week five. There is also a clear tendency of elevation in all dairy breeds SCC from week five to week eight. Meanwhile, in the indigenous does which scored the lowest milk SCC, stability prevailed in the exception of an increase in week five. This stability in the indigenous milk SCC is reminding the stability reflected in the indigenous milk yield (Graph 4.1), milk lactose (Graph 4.2) and milk fat percentage (Graph 4.4) where it was explained that the indigenous does were under a homeostatic control which was reflected by stability in its milk yield and components.

As for the dairy breeds milk SCC elevation, it can be explained by Petzer *et al.* (2008) who investigated the value of using the SCC in the assessment of the dairy goats udder health; a higher SCC in mid and late lactation was found, as compared to SCC from early lactation milk. They said that breed, stage of lactation and milk yield needed

to be taken into account when using SCC as a measure of udder health in goats. This warning is in agreement with Barth *et al.* (2010) who recently said that a high variability of SCC in goats' milk can be caused by infection, but also by physiology (estrus, stage of lactation,) and any other factor not controllable by farm management.

In summary, this erratic SCC performance seen in Graph 4.6 seems difficult to explain and lends a support to Lerondelle *et al.* (1992) who said that the use of SCC for predicting mammary infections is difficult in goats; healthy goat udders can indeed have high SCC levels in their milk normally. Haelein (2002) stated that, although a maximum of PMO remains acceptable at $1 \times 10^6 \text{ ml}^{-1}$, it is not advisable to use SCC (as it is the case in dairy cows), as an index of goat mammary health status.

Further researches need to be conducted to ascertain the reason why the Indigenous and the Alpine goats do present a reverse pattern of SCC levels respectively in the beginning (from week one to two) and in a more advanced stage of lactation (week three to eight).

4.3 Effect of breed on milk yield and components

The effect of breed on milk yield and constituents is presented in Table 4.8.

Table 4.8: Effect of breed on mean milk yield and constituents (\pm SD) in milk of lactating does herded in the same environment

Variables	Fat (%)	Lactose (%)	Protein (%)	MUN (ml/dl)	SCC (x1000)	M. Yield (ml)
Breeds						
B. Alpine	5.1 ± 0.39	4.6 $\pm 0.13^a$	4.6 $\pm 0.30^a$	27.3 ± 1.12	8905 $\pm 167^{ab}$	1.9 $\pm 1.40^a$
Indigenous	5.6 ± 0.56	4.6 $\pm 0.19^a$	5.0 $\pm 0.44^a$	28.8 ± 1.70	800.1 $\pm 2410^a$	0.9 $\pm 1.89^b$
Saanen	5.6 ± 0.27	3.8 $\pm 0.09^b$	5.7 $\pm 0.21^b$	26.1 ± 0.84	13096 $\pm 1181^b$	1.6 $\pm 9.1^a$
Toggenburg	4.5 ± 0.32	3.6 $\pm 0.11^{bc}$	3.0 $\pm 0.25^c$	24.1 ± 0.98	12551 $\pm 1386^b$	2.0 $\pm 1.1^{ac}$
p-value	0.065	$p < 0.01$	$p < 0.01$	0.017	$p < 0.01$	$p < 0.01$

Means per column followed by a different superscripts (^{a, ab, bc}) do significantly ($p \leq 0.01$) differ

Table 4.8 shows that goat breed had an influence on lactose, milk proteins, SCC and milk yield. The data in Table 4.1 and Graph 4.1 suggested that the indigenous herded in the same environmental conditions as dairy breed of goat (Saanen, British Alpines and Toggenburg) yielded lower milk than these dairy breeds; and among dairy breeds, milk yield performance could be schematized as : Saanen < B Alpine < Toggenburg breeds. Each breed of goat achieving its own milk yield record in an environment where feeding management was the same is a clear demonstration that individual factors attached to does genotype are responsible for differences in milk yield performance. Our results are in agreement firstly with Mioč *et al.* (2007) who studied the factors affecting milk yield and constituents in the Czech Republic and found that daily milk was significantly affected by breed (Saanen higher than Alpine goats). Secondly, our results are also in agreement with Sanogo *et al.* (2010) who investigated milk yield performance of Crossbred sahelian goats in Mali and concluded also that daily milk production was highly affected by breed.

As for lactose, Table 4.8 shows that it is dictated by breed. Lactose is the most important osmotic solute for milk yield (Bell, 1995). Lactose importance in determining milk volume is such that, if lactose secretion ceases, milk volume will be greatly reduced (Pulina, 2002); anything that affects lactose, also affects milk yield (Rook *et al.*, 1966). The view that milk secretion rate depends on lactose secretion was expressed by Linzell (1973); it has been reviewed in this study on the correlation matrix presented in Table 4.9. Results in this Table 4.9 (next page) surprisingly indicate a lack of correlation between lactose and milk yield; but in this same study when the correlation matrix excluded BCS and focused on differences between indigenous and dairy breed of goats, milk yield showed a positive correlation with lactose in all lactating does (Table 4.10, next page). Therefore, if breed determines milk yield (Table 4.8) and milk yield depends on lactose (Table 4.10), then breed controls also lactose; that is what is reflected in Table 4.8. Table 4.8 also shows that breed has an effect on milk protein. Table 4.9 (next page) shows a negative correlation existing between milk yield and milk protein.

Many authors (Kennedy *et al.*, 1980; Bouloc, 1987 Rabasco *et al.*, 1993; and Todaro *et al.*, 2005) have reported and supported the view that a negative correlation

exists between milk yield and protein percentage. In this study Table 4.8 suggested that milk yield was influenced by breed.

Table 4.9: Correlation matrix between BCS, milk components and blood parameters from all does during eight weeks of lactation.

Variables	BCS	Glucose	Cholesterol	Urea	Fatacids	Milkyield	Lactose	MilkProtein
BCS	1	0.087	-0.185	-0.106	-0.198	-0.243	0.187	0.018
Glucose	0.087	1	-0.299	-0.140	-0.251	-0.198	-0.042	0.121
Cholesterol	-0.185	-0.299	1	0.220	-0.060	-0.084	-0.271	-0.024
Urea	-0.106	-0.140	0.220	1	0.041	-0.092	-0.030	-0.006
Fatacids	-0.198	-0.251	-0.060	0.041	1	0.285	0.007	0.095
Milkyield	-0.243	-0.198	-0.084	-0.092	0.285	1	0.008	-0.210
Lactose	0.187	-0.042	-0.271	-0.030	0.007	0.008	1	-0.257
MilkProtein	0.018	0.121	-0.024	-0.006	0.095	-0.210	-0.257	1
Milkfat%	0.079	0.165	0.080	-0.237	-0.234	-0.083	-0.311	0.397
MilkUreaN	-0.039	-0.056	0.031	0.223	-0.010	-0.264	0.053	0.151
SCcount	-0.216	-0.015	0.185	0.143	0.079	-0.009	-0.702	0.135

Values in bold are significantly different from 0 with a significance level $\alpha=0.05$

Table 4.10: Correlation matrix between milk components and blood parameters of does from indigenous (Ind.) and dairy (D) breeds.

Breeds: Dairy & Indigenous	Ind	D	Ind	D	Ind	D	Ind	D	Ind	D	Ind	D	Ind	D	Ind	D	Ind	D	Ind	D
Fat %																				
Protein		+																		
Lactose		-	+	-																
S.C.C					±	-														
Milk urea				+																
Milk yield					+	+	+	+		-										
Glucose	±				÷															
Cholesterol			-		÷	-		+		-	-		-							
Blood urea Nitrogen	+	-	±					+	+	+				-	+					
F. Fat Acids		-		+	-		+				+		-							
Milk & Blood Components	M Fat %		Protein		Lactose		SCC		MUN		Milk yield		Glu		Cho		BUN		FFA	

Legend: (+) means positively correlated; (-) negatively correlated; (±) positive tendency to correlate; (÷) negative tendency to correlate.

Therefore, milk proteins being in a reverse relational equation (dilution effect) with milk yield should explain why breed is also negatively correlated to milk protein. Looking at Table 4.4 and Graph 4.3, one can see that each breed of goat displayed its own milk protein record just as it was the case with the goat's milk yield performance. This is an additional proof that, in the lactating does, breed does indeed influence milk proteins. Concerning the goat milk SCC, Table 4.8 showed that it was dictated by breed; but, results obtained with Indigenous does SCC and the conflicting theories supporting on one hand the gradually increasing SCC (Table 4.7 and Graph 4.6) and on the other, an initial increase followed by a gradually decreasing SCC do not allow us to draw a clear picture on the real driving forces acting behind the SCC in the goat's milk. Further studies are needed to review firstly the influence of breed on milk SCC, and secondly the milk SCC negative correlation with milk lactose seen in this study in Table 4.9.

Table 4.9 on correlation matrix showed also the existence firstly, of a negative correlation between SCC with both BCS and lactose; and secondly a positive correlation existing between SCC and blood cholesterol. Those results will be discussed later, separately, in the relevant chapters.

4.4 Conclusions

Data relative to the effects of goat breed on milk yield and components suggest that:

- Breed has an impact upon milk yield which, in turn, is positively correlated with lactose and negatively correlated with both milk fat and milk protein (Dilution effect); breed has therefore, a control upon lactose, milk fat and milk protein
- Milk yield of dairy goat is superior to milk yield of the indigenous; but milk from indigenous does has a higher lactose, milk proteins, milk fat and MUN content
- MUN appears to be a direct reflection of BUN concentrations as shown by the correlation matrix in Table 4.9 and table 4.10.
- In goats, SCC in milk is not a reliable mammary health status index; the SCC relationship with breed (Table 4.8) and lactose (Table 4.9) found in this study needs to be ascertained.

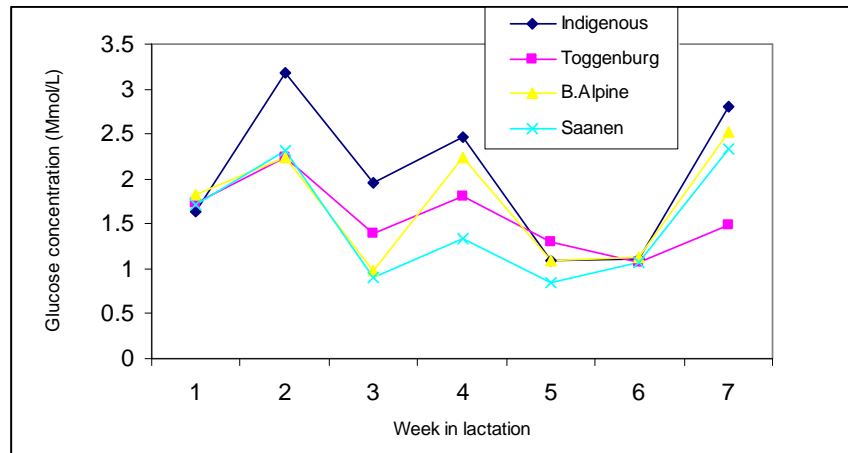
- The onset of lactation exacerbated by a poor nutritional supply, shifted the nutritional partitioning process of goats into an homeorhetic regime in all dairy breeds, while a strict homeostatic control prevailed in the indigenous goat.
- With the provision of feed supplement, Toggenburg had the highest milk yield (Graph 4.1) of the trial. The British Alpine scored second and demonstrated the independency of its milking capability from grazing quality. Saanen does yielded less milk than the other dairy breeds (but more milk than the indigenous does). It lost most body condition.

CHAPTER 5

Results and discussion: Effect of goat breed on selected blood metabolites associated with milk production.

5.1 Blood glucose concentrations

Results of blood glucose concentrations are presented in Graph 5.1.



Graph 5.1: Blood glucose concentrations of Indigenous and Dairy does during the first seven weeks of lactation.

In this graph, a repeated sequence of “rise and fall” pattern is apparent in the indigenous blood glucose concentration which was significantly ($p \leq 0.001$) higher during the first four weeks of lactation compared to the other breeds blood glucose. A low glucose concentration (week one) is typical of early lactation since glucose is used up for lactose synthesis at the onset of lactation (Forsberg, *et al.*, 1985; Blauwiekel *et al.*, 1986; Wiley *et al.*, 1991; Khan *et al.*, 2002). Early lactation usually results in a decreased blood glucose concentration due to the fact that the lactating animal is unable to eat sufficient food to meet its increased metabolic demand at the specific time where a tremendous pressure is exerted upon glucose for lactose synthesis (Rowlands, 1980).

An increased blood glucose concentration is reportedly associated to an increased dietary supply: Food intake is a major determinant of increased blood glucose production during lactation (Lindsay 1991). An increased high glucose concentration in goats fed high energy diets was observed by Sahlu *et al.* (1992) who explained that the increased

glucose production resulted from the increased availability of glucogenic amino acids present in the diet. Among other authors Bergman (1983), Weekes (1991), Hossaini-hilali *et al.* (1993), Landau *et al.* (1993), Rusche *et al.* (1993) and Fike *et al.* (2003) also indicated that an increased feed intake resulted in high blood glucose concentration in lactating animals. That is most probably what happened in this experiment in week two (Graph 5.1) when all goats were fed a feed supplement; their energy intake doubled; glucose concentration could have been raised by this increased dietary supplement.

But, in week three blood glucose concentrations decreased again in all goats. What happened is that feed supplementation in week two was not sufficient to sustain milk production of the grazing goats because nutrient restriction during pregnancy shifted nutrient partitioning into a homeorhetic regime which continued during early lactation (Celi *et al.*, 2008). This, however, was not sufficient to sustain milk production of the grazing goats because, as said Champredon *et al.* (1990), does cannot meet their energy requirement especially if parturition occurred out of season or, during marginal land which in this case was an early spring grazing consisting of Kikuyu (*Pennisetum clandestinum*: GE = 6.8 MJ/ kg; see Table 3.3).

Žubčić (2001) worked on fawn goats in Croatia and attributed hypoglycaemia to energetically insufficient nutrition in terms of lactation level. Sahlu (1993) demonstrated that high amounts of dietary energy are required by high producing goats in early lactation for milk synthesis and secretion. Herbein *et al.* (1985) reported low blood glucose in cows on summer pasture with a limited grain supplement. In this study, the energetically insufficient nutrition might explain the decreased glucose concentration observed in week three.

At week four, the mammary gland needed more milk precursors to carry on with lactation; this necessity enhanced a mechanism of body reserves mobilization which resulted in an increased blood glucose concentration associated to a decline of the BCS (see Table 4.2). Goat BCS is very sensitive to the availability of forages resources on rangeland; underfeeding results in goat BCS decrease (Santucci *et al.*, 1991). In this study in week four, BCS decreased from 2.5 to 2 in the British Alpines and the Toggenburg, and from 2 to 1.5 in the Saanen (see Table 4.2). In summary, the energetically inadequate diet fed during this trial, enhanced in week four in all dairy does, a body reserves

mobilization which entailed not only a BCS decrease in goats, but also an increase in both blood glucose in week four and blood FFA concentrations from week three to week five (Graph 5.3).

As for the Indigenous does, their blood glucose concentrations remained the highest and this is confirmed in Table 5.1 where an Anova on mean blood glucose concentration from all goats is presented.

Table 5.1: ANOVA of mean (\pm SD) blood glucose concentrations from different breed of does in the first eight weeks of lactation

BREEDS	N	Glucose (Mmol/L)
B. Alpine	56	1.7 \pm 0.90 ^a
Indigenous	56	2.0 \pm 0.97 ^b
Saanen	54	1.5 \pm 0.77 ^a
Toggenburg	54	1.6 \pm 0.81 ^a
p/value		0.001
Coeff/variation		34.544
LSD		0.3973

Means per column with different superscript (^a^b) letters differed significantly ($p \leq 0.001$)

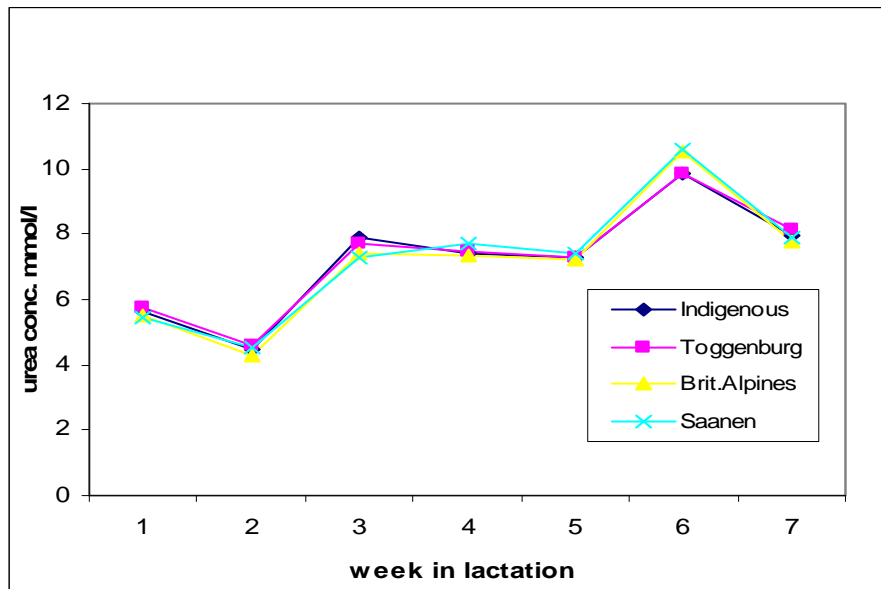
n = number of observations.

This highest concentration of glucose in the Indigenous does blood is a reminder of the highest level of lactose percentage seen in the indigenous does (Table 4.3 and Graph 4.2) where it was explained that the low-yielding goats tended to have a high blood glucose concentration but a poorer mammary uptake for glucose than the high-producing goats (Chang *et al.*, 1996). Lactose being isotonic to glucose concentration is the reason why in this study glucose and lactose remained high in the indigenous goats.

5.2. Blood urea nitrogen (BUN) concentrations

Results on BUN concentrations are presented in Graph 5.2

As apparent, there is a general decrease in BUN in week one followed by a general week two BUN increase. The plateau observed in week four is reflective of missing data. Another BUN increase is seen from week five to week seven.



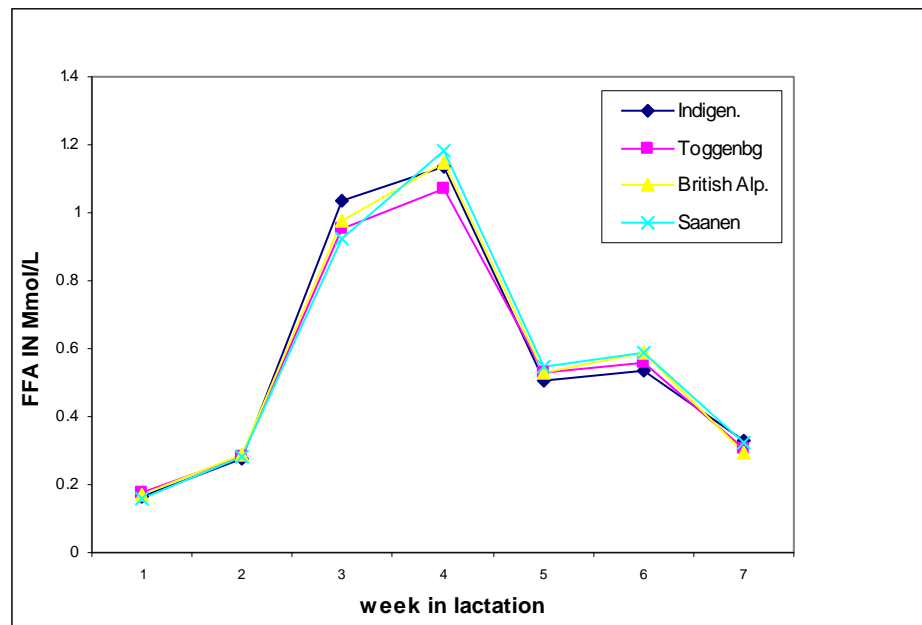
Graph 5.2: BUN concentrations of Indigenous and dairy breeds during the first seven weeks of lactation.

Dietary CP content is the major determinant of urea formation which reflects in BUN and MUN concentrations (Bucholtz *et al.*, 2007; Bonanno *et al.*, 2008). In this study, while discussing the goats' milk yield performance (Graph 4.1) and, the blood glucose concentration (Graph 5.1) it was hypothesized that the early spring pasture was not adequate to support the does early lactation increased energy demand. Early spring (end-winter) kikuyu grass is a “nitrophobe” grass (3.6% N₂, Table 3.3) and therefore a poor CP nutritional supply for the lactating does. That is reflected by the decrease in all does' week one BUN seen in Graph 5.2. But, in week two, when all does were supplemented with the ewes and lamb pellets containing 13% CP and 10% urea (Table 3.3), the week two to three BUN concentrations increased (Graph 5.2).

It has been hypothesized, while discussing blood glucose concentration (Graph 5.1) that at week four, the necessity to provide more and more milk precursors to the mammary gland set up in all does the mechanism of body reserves mobilization which resulted in an increased blood glucose concentration. Results in Graph 5.2 support the above since a high BUN occurring concurrently with both a high blood glucose concentration (Graph 5.1) and a decreased BCS (Table 4.2), is indicative of a body reserves mobilization process (Folman *et al.*, 1981; Nazifi *et al.*, 2000). Ganong (1995) explained this by contending that muscle proteins catabolism resulted in an increased availability of AA. The deamination of those AA in the liver for gluconeogenesis entailed the production of urea. Gluconeogenesis and ureogenesis are linked processes (Bergman, 1983; Belyea *et al.*, 1990). The elevated BUN concentration is typical for an increased ureogenesis (Doepel *et al.* 2002). The body reserves mobilization explains the BUN concentration increase observed in Graph 5.2 from week five to week seven.

5.3 Blood free fatty acid (FFA) concentrations

Blood FFA results are represented in Graph 5.3



Graph 5.3: Blood FFA concentrations of Indigenous and Dairy does during the first seven weeks of lactation.

In Graph 5.3 the general pattern reflects a bell-shape figure and also a striking similarity in all goats FFA performance. This kind of similarity was seen previously in this study's all goats BUN concentrations. Bernard *et al.* (2005) studied the mammary lipid metabolism and milk fatty acid secretion in Alpine does fed vegetable lipids; no variation in plasma NEFA concentration were found and their conclusion was that, in goat, plasma NEFA was not influenced by differences in type and level of fat. This was also the opinion of Miettinen and Huhtanen (1989) who, after inclusion of molasses in the diet of the dairy cows, found no significant effect on the cows NEFA concentrations.

These observations are supportive of the concept that the increased FFA observed in this study was most probably not related to the dietary fat intake. Radloff *et al.* (1966) observed an increased plasma FFA concentration upon fasting and concluded that blood FFA was the better criteria of undernutrition. Later, Chilliard *et al.* (2000) added that the mammary gland needed the NEFA released from adipose tissue as a source of long-chain fatty acids for milk fat synthesis. Doepel *et al.* (2002) stated that in the immediate postpartum period, approximately 50% of the circulating NEFA were needed in order to be incorporated into milk fat. In short, early lactation is associated, in ruminants, with high milk yield subsequent to a considerable mobilization of fat and proteins.

In this study, while discussing milk yield performance (Graph 4.1), blood Glucose (Graph 5.1) and BUN concentrations (Graph 5.2) it was hypothesized that all does were under a nutritional stress and body reserves were subsequently mobilized in order to maintain milk production. Graph 5.3 results are supporting the effectiveness of this nutritional stress: from week two to week five body reserves were massively mobilized to support the milk production metabolism.

An additional interesting feature in Figure 5.3 is the similarity in the performance of all does' blood FFA concentrations. This similarity is hiding another reality that was revealed by the Anova on means blood FFA concentration from all does presented in Table 5.2 (next page).

Results in Table 5.2 show that although all lactating does reflected a similar pattern in Graph 5.3, the indigenous doe's blood FFA concentration still remained lower as compared to their dairy counterparts. This lower FFA concentration in the Indigenous

does might be the reflection of a “compromised response” between 2 antagonist forces: the body reserves mobilization mechanism on one side and on the other, the effort to maintain stability (reflected in the indigenous does BCS maintenance at 3 (Table.4.2).

Table 5.2: ANOVA of mean (\pm SD) blood FFA concentrations from different breed of does during the first eight weeks of lactation

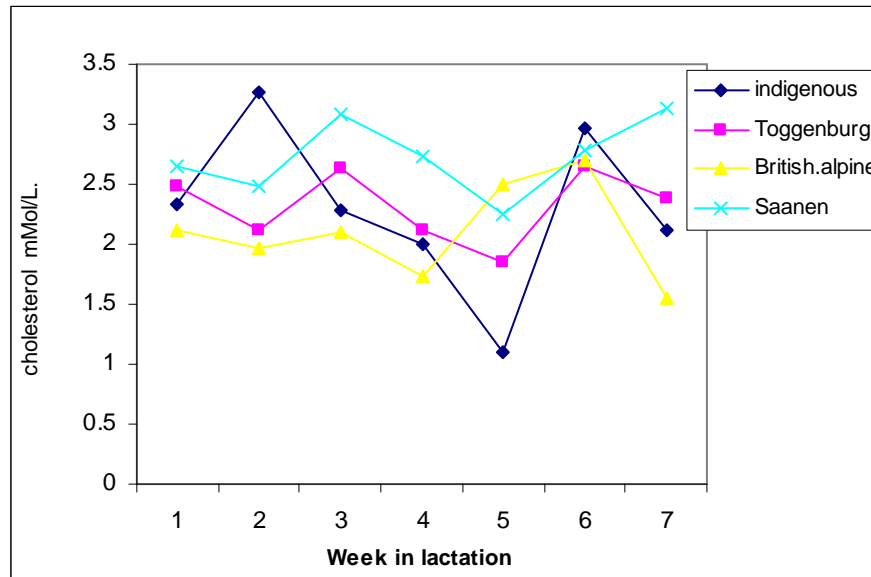
BREEDS	N	FFA (Mmol/L)
B. Alpine	56	0.5 \pm 0.38 ^a
Indigenous	56	0.4 \pm 0.28 ^b
Saanen	55	0.5 \pm 0.37 ^a
Toggenburg	54	0.5 \pm 0.30 ^a
p-value		0.001
Coeff/variation		43.1663
LSD		0.0935

Mean per column followed by different superscript (^a^b) letters differed significantly ($p \leq 0.001$)
n= number of observations.

Santucci (1991) wrote that blood FFA concentrations are closely linked to the animal energy balance. Caldeira *et al.* (2007) said that FFA provided better substantial information for the diagnosis of the energy status of the animal. Dunshea *et al.* (1989) indicated that during negative energy balance, FFA kinetics reflected a fat mobilization process in lactating does. In the view of the above, the blood FFA global elevation seen in Figure 5.3 means one single and unequivocal message which is “Food inadequacy”: the nutritional diet fed to the lactating does during this trial was inadequate in all breeds; this, added to the early lactation negative energy balance, prompted in all does a lipomobilization mechanism which is reflected by the general FFA concentrations increase observed in all does in Graph 5.3.

5.4 Blood cholesterol concentrations

Results on blood cholesterol concentrations are presented on Graph 5.4. Here again, except for the indigenous performance, the general trend seems to follow the one observed in Graph 5.3 (and at some extend in Graph 5.2).



Graph 5.4: Blood cholesterol concentrations of Indigenous and Dairy breeds of goat during the first seven weeks.

In Graph 5.4 there is a tendency of rise and fall (from week two and five) followed by an elevation from week five to week seven. Zumbo *et al.*, (2007) reported a high cholesterol concentration in mid-lactation and explained it by a strong reduction in lipogenesis which resulted in the epinephrine-stimulated free fatty acids release. Arave *et al.* (1974) studied the genetic and environmental effects on serum cholesterol concentrations of dairy cattle of various age; they reported a relatively low serum cholesterol concentration at the onset of lactation which increased at Mid-lactation and decreased in late lactation. Rowlands (1980) studied the metabolic changes in dairy cows during pregnancy and lactation; he found a significant increase in blood cholesterol concentrations between week one and six post-partum. Nachtomi *et al.* (1991) found an increased blood cholesterol concentration during the first five weeks of lactation in dairy cows. An increased blood cholesterol concentration has also been reported during lactation by Grimoldi *et al.* (1988) and Gaal *et al.* (1993).

Results in this study are joining the ones expressed above, which are all conversant with diagnosis: all does went through a body reserves mobilization process; the fat mobilization (lipomobilisation) prompted by the early lactation high energy demand could have forced the week three to week five blood cholesterol concentration to increase. Cholesterol concentration is indeed, according to Beynen *et al.* (2000), increased by 91% after high fat diets but in the absence of excessive fat intake, it (cholesterol concentration) indicates the ruminant's ability to mobilize fat stores for milk production (Ingraham *et al.*, 1988).

The increase in week five to week seven blood cholesterol concentration seen in Graph 5.4 is a reminder of the week five to week seven BUN increase (Figure 5.2) as well as the FFA increase (Figure 5.3) in week five to week seven. An increase which is the reflection of body reserves lipomobilisation prompted by the early lactation negative energy balance occurring in a context of a poor nutritional supply fed to the lactating does.

In Table 4.9 (page 69) the correlation matrix suggested that blood cholesterol was negatively correlated to BCS, to blood glucose and to milk lactose while it was positively correlated to SCC and to BUN. Table 4.10 (page 69) confirmed on one hand the existence of a Cholesterol negative correlation to glucose and lactose, and on the other its positive correlation to SCC. SCC has been already discussed (point 4.7: Effect of breed on milk yield and components) where it was said that based on the available literature, this was difficult to explain. The correlation between cholesterol and BCS will be discussed in chapter 6.

Coming back to the cholesterol negative correlation with glucose and lactose (Table 4.9 and Table 4.10), it can be explained once again by the dilution effect: Glucose and lactose are both milk yield precursors; high milk yield depresses the fat component of milk (of which cholesterol is a major component), while low milk yield is associated to high milk fat percentage. Glucose and lactose are therefore at the reverse (negative) positional equation with cholesterol whence the negative correlation reported by Table 4.9 and Table 4.10. This explanation is supported by Iloeje *et al.* (1981) who studied the components in variance of milk and fat yields in dairy goats and came to the conclusion that milk yield and fat percentage were negatively correlated.

The correlation matrix in Tables 4.9 and 4.10 are also indicating the existence of a positive correlation existing between Cholesterol and BUN. This can be explained by the fact that cholesterol and BUN are both metabolites “of same season” in the sense that they appear (are increased) in a context of body reserves mobilization. This explanation is supported by Folman *et al.* (1981) and Nazifi *et al.* (2000) who reported a high BUN occurring concurrently with a reduced BCS, as typical to a process of muscle protein catabolism. Supporting the same view Ingraham *et al.* (1988) suggested that in the absence of excessive fat intake, high cholesterol concentration was an indication of the ruminant ability to mobilize fat stores for milk production.

From the above, it can assumed that a body reserve mobilization did effectively take place in this trial and, as a consequence both blood cholesterol and BUN concentrations were increased; this explains why blood cholesterol is positively correlated to BUN as suggested by Tables 4.9 and 4.10: blood cholesterol and BUN are both, in some respect, food crisis indicators. This interpretation of blood cholesterol concentration is however, to be taken cautiously. Krajničáková *et al.* (2003) warned that the puerperal period changes in the metabolic parameters prompted by an increased demand of regulatory mechanisms responsible for involution and tissue processes of the sex apparatus, put cholesterol concentrations under the control of a whole complex of factors involved in the relationship between blood cholesterol and hormones of reproduction. Juma *et al.* (2009) discussed the effect of some hormones on reproductive performance and some serum biochemical changes in black goats; they ended up concluding that total cholesterol increased significantly during pregnancy (progesterone effect) and decreased after parturition (oestrogen effect). These considerations make it difficult to take cholesterol concentrations as an absolute nutritional stress indicator.

5.5 Effect of goat breeds on selected blood metabolites associated with milk production

Results on the breed effect upon selected blood metabolites associated to milk yield production are presented in Table 5.1 (next page) where cholesterol appears to be the only and unique blood metabolite which is affected by breed. The notion of breed being related to blood cholesterol is well documented in human medicine where blood

cholesterol is reportedly higher in the black population of USA than in the white Caucasian population of Asia (Bauer, 2007); in animal science however, little has been published on blood cholesterol in goat.

Table 5.3: Effect of breed on selected blood parameters (\pm SEM) associated with lactation in does raised in the same environment.

Variables	Glucose (Mmol/l)	Cholesterol (Mmol/l)	BUN (Mmol/l)	FFA (Mmol/l)
BREEDS				
B. Alpine	1.9 ± 0.17	2.5 $\pm 0.11^{ac}$	6.96 ± 0.34	1.6 ± 0.07
Indigenous	1.6 ± 0.25	1.5 $\pm 0.16^b$	6.04 ± 0.50	0.4 ± 0.10
Saanen	1.6 ± 0.12	2.7 $\pm 0.08^a$	7.19 ± 0.24	0.5 ± 0.05
Toggenburg	1.7 ± 0.14	2.3 $\pm 0.09^c$	6.09 ± 0.29	0.5 ± 0.55
p-value	0.492	$p \leq 0.01$	0.010	0.3

Mean per column followed by a different superscript letters do significantly ($p \leq 0.01$) differ.

Table 5.3 showing blood cholesterol as the unique blood metabolite on which breed is having an effect may be a way to underline the importance of cholesterol in the goat milk characterization.

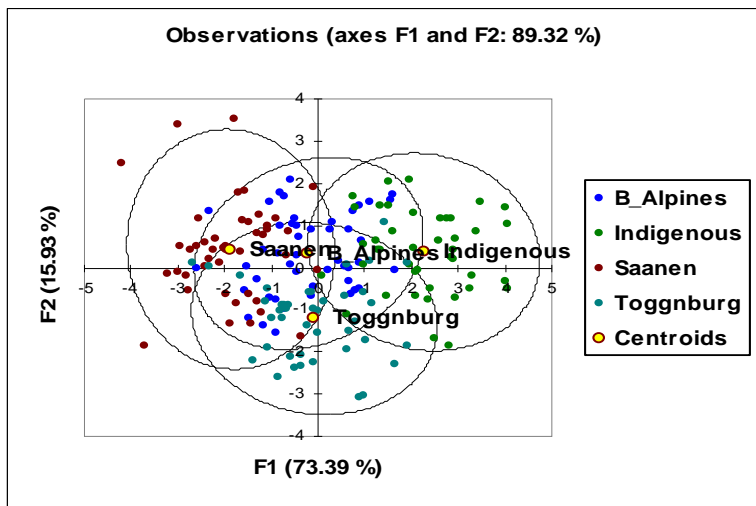
5.6 Critical component analysis of milk yield and milk constituents in different breeds of goats.

Results with blood metabolites are showing that, confronted to a poor nutritional plan in early lactation, the different lactating does mobilized body reserves in order to support the on-going galactopoiesis.

In the case of the indigenous does, they responded to the on-going food crisis by simply stopping lactation on week eight. This sudden drying off probably happened

because in Indigenous does, homeostasis plays a pivotal role in regulating body processes. Apparently, the indigenous doe's basal metabolism is regulated in such a way that stability or general internal equilibrium remains a priority above all other processes.

By contrast, the dairy breeds of goats, because their metabolism is under an homeorrhetic control whereby milk production is a priority at all costs, were still lactating in December (week eight) at the expense of their BCS. As apparent, there was a difference in the way the basal metabolism operated in the lactating does; there was a difference in the priorities given to the food partitioning processes; those differences entailed differences in the performance achieved with milk yield and milk constituents in different breed of does. In this study, these differences were statistically plotted with milk yields as centroids and milk constituents as selected variables; results have revealed a striking lack of homogeneity between all breeds of goat. This is illustrated in Graph 5.5



Graph 5.5. Score plot of factor 1 (milk yield) and factor 2 (milk constituents) showing centroids (yellow spots) level of homogeneity between breeds with 93% of confidence.

The most remarkable feature in Graph 5.5 is the lack of homogeneity (smallest intersection) between the indigenous and the Saanen does. Apparently, a greater overlap exists between the indigenous does and the Alpines and the Toggenburg; while there is little overlap, in terms of suitability (for milk yield and constituents), between the indigenous and the Saanen does. Graph 5.5 seems to indicate a greater tolerance from the

Alpines and the Toggenburg towards the natural indigenous environment in contrast to the Saanen which is struggling (little overlap) to perform in the “indigenous does’ comfort zone.” This result is in agreement with Anifantakis and Kandarakis (1980) who found many differences between those two breeds when they worked on the goat milk constituents from the Indigenous and the Saanen does. Their results revealed significant differences in almost all milk constituents with the indigenous milk being richer in total proteins, fat, solid non-fat and lactose, while the Saanen does produced a higher milk yield with low concentrations in all milk constituents.

5.6 Conclusions

- Results indicated that, in lactating does, breed effect is limited on blood cholesterol only.
- Results also confirm and support the fact that all the lactating does were challenged by a poor nutritional plan; this added to the early lactation negative energy balance enhanced in all does a mechanism of body reserves mobilization aimed at supporting the on-going galactopoiesis.
- Body reserves mobilization prompted (and evidenced by) the elevation in blood glucose, BUN, blood FFA and blood cholesterol concentrations especially between week five and week seven of lactation. This indicates that blood metabolites, when accurately selected and analyzed in relevance with the physiological principles involved, can be useful as an index of the nutritional plan fed to lactating does.
- Results also show that in the indigenous does, homeostasis plays a pivotal role in regulating and stabilizing different body processes while in the dairy breeds of goats a state of homeorrhesis prevails and consequently milk production remains a priority at all costs.
- Finally a statistical score plotting of milk yield and milk constituents have revealed the existence of a greater overlap between the Indigenous and the Saanen does, suggesting that the environment (or farming system) that suits the indigenous is less likely suitable to the Saanen does.

CHAPTER 6:

Results and discussion: Effects of phenotype characteristics on blood metabolites, milk yield and constituents.

6.1 Introduction

The phenotype characteristics considered in this study included breed, BCS, udder characteristics and age. Breed has been already discussed in points 4.7 and 5.5. In chapter 6 the parameters of interest will be BCS, Udder size, udder attachment and age. All parameters will be correlated firstly to milk yield and milk constituents; and secondly to blood metabolites.

6.2 Effects of phenotype characteristics on milk yield and constituents

The stepwise discriminant analysis conducted in this study (Table 6.1) showed that, when it comes to milk characterization in goats, BCS is at a level of confidence of 54%, the most important variable; followed by milk yield (32% level of confidence) and cholesterol (19% level of confidence). BCS will therefore be discussed first.

Table 6.1: Stepwise discriminant analysis between body characteristics and milk constituents associated with blood metabolites

Variables	Variable IN	Partial R ²	F	Pr > F	Wilks'Lambda	Pr<Lambda
1 BCS	BCS	0.539	66.607	< 0.0001	0.461	< 0.0001
2 BCS / Milkyield	Milkyield	0.322	26.957	< 0.0001	0.312	< 0.0001
3 BCS / Cholesterol / Milkyield	Cholesterol	0.189	13.128	< 0.0001	0.253	< 0.0001
4 BCS / Cholesterol / Milkyield / / MilkProtein	MilkProtein	0.110	6.935	0.000	0.225	< 0.0001
5 BCS / Cholesterol / Milkyield / Lactose / MilkProtein	Lactose	0.123	7.777	< 0.0001	0.198	< 0.0001
6 AGE / BCS / Cholesterol / Milkyield / Lactose / MilkProtein	AGE	0.104	6.429	0.000	0.177	< 0.0001
7 AGE / BCS / Cholesterol / Milkyield / Lactose / MilkProtein / MilkUreaN	MilkUreaN	0.081	4.853	0.003	0.163	< 0.0001

6.2.1: Effect of BCS on milk yield and constituents

Results on the effect of BCS upon milk yield and constituents are presented in Table 6.2 (next page) where it is appearing that BCS had an influence on fat percentage, lactose, milk proteins but not on MUN, SCC and milk yield.

Table 6.2: Effect of BCS (\pm SEM) on milk yield and constituents in different breeds of does' raised in the same environment

VARIABLES	Fat %	Lactose%	Protein%	MUN/mMol/L	SCC x 1000	M. Yield/ml
BCS						
* 2	4.4 \pm 0.4 ^b	3.8 \pm 0.1 ^b	3.5 \pm 0.3 ^{ab}	27.9 \pm 1.2	13690 \pm 18	1463 \pm 14
* 2.5	4.3 \pm 0.4 ^a	4.4 \pm 0.1 ^b	4.3 \pm 0.3 ^a	9.7 \pm 1.1	8246 \pm 15	1667 \pm 12
* 3.	6.2 \pm 0.3 ^b	4.2 \pm 0.1 ^b	5.1 \pm 0.2 ^{ac}	24.2 \pm 0.1	8885 \pm 13	631 \pm 10
p-value	p \leq 0.05	p \leq 0.01	p \leq 0.02	0.011	0.014	1.000

Mean per column followed by a different superscript letters do significantly (p \leq 0.05) differ

6.2.1.1: BCS and Milk yield

Our previous results (Table 4.10) showed a positive correlation between milk yield and lactose. In theory, anything that affects lactose, affects also milk yield (Faulkner *et al.*, 1980; Bell, 1995; Pulina, 2002). This is not what is appearing in Table 6.2. To verify these results an ANOVA between BCS and milk yield is presented in Table 6.3.

Table 6.3: Effect of BCS on milk yield (in ml) of different lactating does.

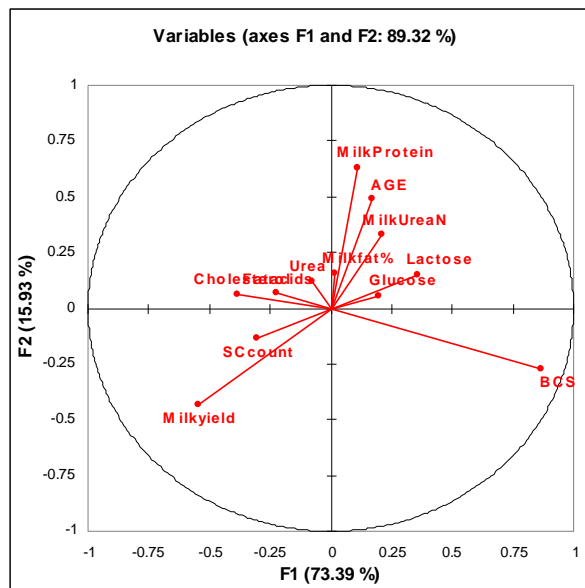
Does. BCS	n	Milk yield(ml)
		Mean+ Std Dev
1.5	28	1300 \pm 56 ^a
2	95	1870.147 \pm 81 ^b
2.5	75	1821.973 \pm 83 ^b
3	53	877.283 \pm 58 ^c
p-value		0.001
R-square		0.496539
Coefficient/Variation		43.15020

Mean per column followed by different superscript (^{a b}) letters differed significantly (p \leq 0.001)
n=number of observation

Results in Table 6.3 do indicate that BCS has indeed an influence on milk yield.

The explanation about BCS being negatively correlated to milk yield (Table 6.3) might be that, in early lactation 80 % of does experience negative energy balance; and because the energy demands for milk yield are not met by diet, the individual doe responds by mobilizing body resources. In species like the cow, goat and pigs the magnitude of this body reserves mobilization is such that milk yield is maintained high while body reserves (reflected by BCS) is depressed (Santucci *et al.*,1991; Domecq *et al.*,1997; Roche *et al.*, 2007). Whence the negative correlation between (high) milk yields and (low) BCS.

In this study, results in Table 6.3 shows that does with the best BCS (BCS 3: Indigenous) yielded the lowest milk yield (877 ml) while, does with the highest milk yield (Toggenburg: 1868 ml/day) lost more BCS (from 3 to 2; see Table 4.2). As evidenced in this study (Table 4.10, Table 6.3), an overall negative correlation does exist between mean BCS and milk yield (Santucci *et al.*, 1991; Cabiddu *et al.*, 1999). This has been also confirmed in Graph 6.1 where a diagrammatic representation of correlations between milk constituents, blood metabolites, BCS and age is presented.



Graph 6.1: Diagrammatic representation of correlations between milk, blood, age and BCS from different breeds of goat after eight weeks of lactation. Variables on F1 axis were analyzed at the level of 73.4% accuracy while F2 were analyzed with 16% accuracy. The further the value is from the centre, the more significant it is. The closer the values are among themselves, the greater their level of correlation.

Graph 6.1 is reporting and/or supporting many interesting concepts; some of which have been earlier advocated; some others will be discussed later in this study. Back in Graph 6.1 one can see:

- A strong negative correlation existing between BCS and milk yield.
- A negative correlation opposing milk yield to milk protein, MUN and Fat %.
- A strong positive correlation existing between lactose and glucose.
- A positive correlation existing between FFA, cholesterol and BUN.
- A strong negative correlation opposing BCS to FFA, cholesterol and BUN.
- A negative correlation opposing milk yield to blood glucose and lactose.
- A negative correlation opposing cholesterol to glucose, lactose and BCS.
- A negative correlation opposing Age to BCS and milk yield.
- A negative correlation opposing BCS to SCC.
- A tendency for Age to correlate positively with milk protein and MUN.

6.2.1.2: BCS and milk constituents

Table 6.2 (page 86) showed that BCS had an effect on lactose, milk protein, fat %. As seen earlier BCS has an effect on milk yield. Milk yield in turn is in a negative relational equation called “Dilution Effect” with 1) milk proteins (muscle catabolization) and 2) with fat % concentration (lipomobilization) (Rabasco *et al.*, 1993; Landau *et al.*, 1993; Zumbo *et al.*, 2007;). This negative correlation is explained by the fact that during lactation (especially in early lactation) goat dairy breeds physiology enhances a body reserves mobilization (resulting in a lowered BCS) aimed to support milk yield. The notion that, BCS has an effect on milk proteins and fat% has been evidenced in this study (Graphs 4.3 and 4.4) where the Indigenous does had a BCS 3 and recorded a higher proteins and higher fat content in the milk; while the Toggenburg does with a BCS 2 recorded the lower milk protein and lower milk fat (Graphs 4.1, 4.2, 4.3 and 4.4).

As for lactose, Table 6.2 shows that it also is affected by BCS: lactose is isotonic to milk yield; therefore, BCS (which has an effect on milk yield) does also affect lactose. In this study, does with BCS 2 displayed a lowest level of lactose; while does with BCS 3 reflected a higher level of lactose; the difference has most probably been caused by the way these animals used the available lactose. Goats with a BCS 3 (mostly the

Indigenous) yielded less milk. Low yielding breed of goat have usually a poorer uptake of lactose (Chang *et al.*, 1996) whence the higher amount of lactose recorded. On the other side, does with BCS 2 yielded a higher amount of milk but scored a lower lactose concentration precisely because all the available lactose was used up for milk production; lactose, as said earlier the major precursor of milk yield (Faulkner *et al.*, 1979; Bell, 1995; Pulina, 2002).

Talking about the effect of BCS on SCC, Graph 6.1 (page 87) and Table 4.9 (page 69) reported a negative correlation existing between these two parameters. This would have been relatively simple to explain if it was not for the SCC erratic results recorded in Graph 4.6 (page 65). It is indeed tempting to suggest that, the healthier the goat udder is, the better (higher) its BCS (and therefore the lowest its milk SCC) will be. On the reverse, an infected udder is more likely to exert a lowering pressure on the goat BCS while increasing its defensive mechanisms reflected in an increased milk SCC. Such an explanation would have been ideal for a negative correlation opposing BCS to SCC. Further investigations are welcome to ascertain results in Graph 4.6 (page 65).

6.2.2: Effect of udder size on milk yield and constituents

Results on udder size effect on milk constituents are presented in Table 6.4

Table 6.4: Effect of udder size on milk yield and constituents (\pm SEM) of different breeds of lactating does.

VARIABLES	Fat%	Lactose (%)	Protein (%)	MUN(Mmol/L)	SCC(x 1000)	M. Yield (ml)
UDDER Size						
Large	5.709 \pm 0.38	3.87 \pm 0.13	5.5 \pm 0.30 ^{ab}	28.03 \pm 1.16	10873 \pm 1641.	1863 \pm 128.1 ^a
Medium	5.020 \pm 0.17	4.09 \pm 0.06	4.02 \pm 0.13 ^{ac}	26.0 \pm 0.52	9724.5 \pm 737.7	1695 \pm 57.5 ^b
Small	5.395 \pm 0.35	4.4 \pm 0.12	4.70 \pm 0.30 ^a	27.4 \pm 1.06	7205.4 \pm 1498	1243 ^c \pm 117
p-value	0.189	0.02	$p \leq 0.01$	0.175	0.236	$p \leq 0.01$

Mean per column followed by a different superscripts (^{a,b,c}) letters did significantly ($P \leq 0.05$) differ.

In table 6.4 it can be seen that udder size has an influence on both milk yield and milk proteins. Many authors (Linzell, 1973; Linzell, 1975; Gall, 1980; Mellado *et al.*, 1991) have concluded to a significant positive correlation between milk yield and udder volume. Capote *et al.* (2006) found that the globulousness of the udder was correlated with milk yield. But milk yield being subject to much variation both between and within breeds (Pulina, 2002; Makun, 2008; Richardson, 2009), this correlation between udder size and milk yield needed to be verified by an ANOVA. Results are presented in Table 6.5

Table 6.5: ANOVA of udder size on milk yield (in ml) of different breeds of does' (Large, Medium and Small udder sizes)

Udder Size	n	Milk yield (ml)
		Mean+ Std Dev
Large	39	191.5 ± 813 ^a
Medium	172	161.3 ± 864 ^b
Small	40	112.0 ± 587 ^c
p-value		0,0356
R-square		0.25889
Coefficient/Variation		49.846

Mean per column followed by different superscript (^{a,b}) letters differed significantly ($p \leq 0.001$)

n= number of observations

In Table 6.5 it appears that milk yield does significantly differ ($p \leq 0,001$) between milk from large and small udder. The conclusion is that, in goats, udder size is a reflection of milk yield potentialities.

Udder size also affects milk protein (Table 6.4, page 89). In Graph 6.1 (page 87) and Graph 4.3 (page 59) a negative correlation equation was reported between milk protein and milk yield. Udder size being a reflection of milk yield, and milk yield being in a reverse positional equation with milk protein, implies that udder size is also in a negative correlation equation with milk protein. That is what is shown in Table 6.4 (page 89).

6.2.3: Effect of udder attachment on milk yield and constituents

Results on udder attachment (Table 6.6, below) show a positive correlation with milk yield. This also has been verified by an ANOVA between udder attachment and milk yield. Results are presented in Table 6.7.

Table 6.6: Effect of udder attachment on mean milk yield and constituents (\pm SEM) of different breeds of lactating does (well attached, medium and hanging udders).

VARIABLE	Fat (%)	Lactose (%)	Protein (%)	MUN (Mmol/L)	SCC (x1000)	M. Yield (ml)
UDDER Attachment						
* Well	5.342 ± 0.16	4.145 ± 0.05	4.549 ± 0.13	26.903 ± 0.50	8885.8 ± 699.14	1489.8 $\pm 54.5^a$
* Hanging	4.884 ± 0.50	3.968 ± 0.17	3.989 ± 0.34	25.543 ± 1.60	122113 ± 2130.3	2295.8 $\pm 166^b$
* Medium	4.591 ± 0.76	4.064 ± 0.25	4.201 ± 0.60	27.003 ± 2.3	8513.2 ± 32559	1802.5 $\pm 251^{ab}$
p-value	0,521	0,625	0,404	0,693	0,330	$p \leq 0.01$

Mean per column followed by a different superscript letters (^{a,b,ab}) do significantly ($p \leq 0.05$) differ.

Table 6.7: ANOVA of the effect of udder attachment on milk yield (in ml) of different breeds of lactating does (hanging udder and the well attached udder groups).

Level of Udder attachment	n	Milk yield (ml)
		Mean \pm Std Dev
Hanging	32	208.4 \pm 838 ^a
Well attached	219	151.1 \pm 824 ^b
p-value		0.0270
R-square		0.223160
Coefficient/Variation		49.770

Mean per column followed by different superscript (^{a,b}) letters significantly ($p \leq 0.05$) differed.

n=number of observations

Results are that the hanging udders group is higher in milk yield than the well attached udders group; which means that in goats, udder attachment does indeed have an effect on milk yield. These results can be explained by the descriptive anatomy of the goat udder: In many cases, udder attachment is a reflection of udder size. If large udder size means high milk yield volume (Table 6.4 page 89, Table 6.5, page 90), so does hanging udder attachment. Conversely, a well attached udder might reflect a small udder and therefore, a low milk yield.

6.2.4 Effect of age on milk yield and constituents.

Results of age effect on milk constituents are presented in Table 6.8.

Table 6.8: Effect of age on mean (\pm SEM) milk yield and constituents of different breeds of goats.

VARIABLE S	Fat (%)	Lactose(%)	Protein (%)	MUN (Mmol/L)	SCC (x1000)	M. Yield (ml)
AGE (Yrs)						
* 1	5.263 \pm 0.302	4.276 \pm 0.102	4.03 \pm 0.235	26.891 \pm 0.92	8631.6 \pm 1302	1529.9 \pm 101.6
* 2	5.24 \pm 0.289	4.091 \pm 0.097	4.66 \pm 0.255	26.598 \pm 0.88	10287 \pm 1244	1719.3 \pm 97.03
* 4	5.23 \pm 0.213	4.026 \pm 0.072	4.59 \pm 0.166	26.671 \pm 0.65	9189.4 \pm 9193	1614.9 71.7
p-value	0.99	0.138	0.12	0.97	0.67	0.45

No significant difference

In Table 6.8 it appears that age does not have any effect either on milk yield or on milk constituents. Some authors however, (Ilahi *et al.*, 1999; Bogdanović *et al.*, 2010), have supported the notion that age had an influence on milk yield. Our results on Graph 6.1 (page 87) suggested also that age was negatively correlated to milk yield. To verify the truth on this subject, an ANOVA between age and milk production was done in Table 6.9 (next page) where it appears as it did in Table 6.8, that age does not affect either milk yield or milk constituents.

Table 6.9: ANOVA of effect of age on milk yield (in ml) of different breeds of goats.

AGE (in years)	n	Milk yield(ml)
		Mean+ Std Dev
1	72	174.167 ± 928
2	48	159.958 ± 616
4	131	149.160 ± 864
p-value		0.3565
R-square		0.188489
Coefficient/Variation		51.79863

No significant difference. n=number of observations.

These results are conversant with those from our discriminant analysis (Table 6.1, page 85) where it was suggested that, in goat, the level of confidence in using age for milk characterization is only of 10%. Age effect (if any) on milk yield, is null in this study.

6.3 Effect of phenotype characteristics on blood metabolites.

6.3.1. Effect of BCS on blood metabolites

Results of the effect of BCS on the blood parameters are shown on table 6.10

Table 6.10: Effect of BCS on mean blood parameters (±SEM) in different breeds of goats (grouped under BCS 1.5, 2 and 3)

VARIABLES	Glucose (Mmol/L)	Cholesterol. (Mmol/L)	BUN (Mmol/L)	FFA (Mmol/L)
BCS				
* 1.5	1.2 ± 0.18 ^a	2.4 ± 0.12 ^a	7.7 ± 0.40 ^a	0.6 ± 0.07
* 2	1.4 ± 0.16 ^a	1.7 ± 0.10 ^b	7.1 ± 0.2 ^b	0.48 ± 0.07
* 3	2.1 ± 0.14 ^b	2.6 ± 0.09 ^a	5.9 ± 0.30 ^b	0.5 ± 0.06
p-value	p ≤ 0.05	p ≤ 0.01	p ≤ 0.05	0.359

Mean per column followed by a different letter were significantly (P ≤ 0.05) different.

Table 6.10 appears to show that BCS has an effect on blood glucose, cholesterol and BUN. In this study, while discussing cholesterol concentration (in point 5.4), it was assumed that BUN and cholesterol were “birds of same feathers”, meaning they were appearing in a context of body reserves mobilization subsequent to an early lactation nutritional stress (Folman *et al.*, 1981; Ingraham *et al.*, 1988 and Nazifi *et al.*, 2000). In Graph 5.1 (page 72), while discussing blood glucose concentration, it was said again that the mobilization of body reserves entailed a gluconeogenesis mechanism which boosted blood glucose concentrations. Subsequent to the gluconeogenesis mechanism, a ureogenesis process was prompted with the resulting increased BUN concentrations seen in all lactating does. Results in Table 6.10 therefore support those in Graph 6.1 (page 87) where it is reported that a negative correlation equation opposed BCS to blood glucose, BUN, cholesterol and FFA concentrations. Once again the explanation is that changes in BCS is a reflection of changes in the metabolic process (in this case the enhancement of a body reserves mobilization) which creates changes in the blood metabolites concentrations. Table 6.10 reveals that does with BCS 3 were significantly different in blood glucose ($p \leq 0.05$), cholesterol ($p \leq 0.01$) and BUN ($p \leq 0.05$) concentrations from does with BCS 2. The conclusion is that BCS does indeed affect blood metabolites as reported in Table 6.10

6.3.2 Effect of udder size on blood parameters

Results on the effects of udder size on blood parameters are presented in Table 6.11 (next page) where it appears that in goats, udder size is related to blood cholesterol only.

These results can be explained, once again, by the dilution effect: Udder size meaning milk volume; and milk volume being in a reverse proportional equation (dilution effect) with the fat component of milk, implies that the fat percentage of blood (of which blood cholesterol is a major component) is also in a reverse proportional equation with udder size. It is however surprising that udder size does not affect FFA, which is also in a reverse proportional equation with milk yield

Table 6.11: Effect of udder size on mean (\pm SEM) blood parameters in different breeds of does grouped in accordance with the large, medium or small size of their udders

VARIABLES	Glucose (Mmol/l)	Cholesterol (Mmol/l)	BUN (Mmol/l)	FFA (Mmol/l)
Udder size				
* Large	184 ± 0.17	2.046 $\pm 0,01^a$	7.291 ± 0.34	0.596 ± 0.07
* Medium	1.727 ± 0.07	2.189 $\pm 0.05^a$	6.392 ± 0.32	0.509 ± 0.03
* Small	1.539 ± 0.16	2.753 $\pm 0.10^b$	6.718 ± 0.27	0.5 ± 0.06
p-value	0.435	$p \leq 0.01$	0.044	0.967

Mean per column followed by different superscript (^{a,b}) letters do significantly ($P \leq 0.05$) differ.

6.3.3: Effect of udder attachment on blood parameters

Results on effect of udder attachment on blood parameters are presented in Table 6.12.

Table 6.12: Effect of udder attachment on mean blood parameters (\pm SEM) in different breeds of lactating does

VARIABLES	Glucose (Mmol/l)	Cholesterol (Mmol/l)	BUN (Mmol/l)	FFA (Mmol/l)
Udder attachment				
* Good	1.647 ± 0.07	2.253 ± 0.05	6.625 ± 0.36	0.506 ± 0.03
* Medium	1.981 ± 0.22	2.338 ± 0.14	6.696 ± 0.32	0.477 ± 0.09
* Hanging	1.834 ± 0.34	2.19 ± 0.22	6.741 ± 0.3	0.543 ± 0.14
p-value	0.385	0.787	0.980	0.908

No significant difference

No correlation was found between udder attachment and any of the selected blood metabolites.

6.3.4 Effect of age on blood metabolites.

Results on effect of age on blood parameters are seen in Table 6.13. These results suggest that in goats, age has an effect on blood cholesterol only.

Table 6.13 Effect of age on blood metabolites (\pm SEM) of different lactating does after eight weeks lactation

VARIABLES	Glucose (Mmol/L)	Cholesterol (Mmol/L)	BUN (Mmol/L)	FFA (Mmol/L)
AGE (Years)				
* 1	1.751 \pm 0.14	1.963 \pm 0.08	6.492 \pm 0.27	0.525 \pm 0.06
* 2	1.938 \pm 0.13	2.535 \pm 0.08	6.729 \pm 0.26	0.499 \pm 0.05
* 4	1.517 \pm 0.01	2.28 \pm 0.06	6.681 \pm 0.20	0.492 \pm 0.04
p-value	0.026	0.01	0.811	0.897

Mean per column followed by a different letter do significantly ($P \leq 0.05$) differ.

This result is congruent with findings made by Sakha *et al.* (2009), who studied the serum biochemistry values of the Raini goat in Iran and found that blood cholesterol concentration was increasing with age. This concept is well documented in human medicine where older people are more prone to high blood cholesterol concentration than the younger ones. But in animal sciences more researches are requested on blood cholesterol concentration in goats.

6.4 Predicting the goat's milking capacity from PTS

Results in Table 4.8 (page 67) have revealed that breed has an effect on milk yield, milk proteins, lactose, SCC and also on blood cholesterol (Table 5.3, page 82).

Results in Table 6.2 (page 86) have showed BCS as being effective on fat percentage, milk protein, lactose and (Table 6.3) milk yield and also (Table 6.8) on blood glucose, BUN and cholesterol. Tables 6.4, 6.5, 6.6 and 6.7 have all demonstrated that

udder characteristics have an effect on milk yield and milk protein and also (Table 6.9) on blood cholesterol. From the above, it has been assumed that, rassembling these parameters (breed, BCS and udder characteristics) in one single package called “phenotype scoring system” (PTS), which will be used to make predictions on the goat’s milkability, might be useful in small scale farming systems. In order to certify this hypothesis, a multiple regression analysis relating to predictions of milkability was conducted. Results are shown in Table 6.14 (below).

Table 6.14: Regression parameters for predicting milk yield (ml/d) from phenotypic characteristics

	equation 1	equation 2	equation 3	equation 4
Constant	0.4798	0.4165	-0.1707	0.1
Udder-size	0.182	0.23	0.235	0.232
P-Value	0.043	0.007	0.006	0.007
Model parameters	Full Model	Reduced Models		
Udder-Attachment	0.37	0.36	0.36	0.36
P-Value	0.008	0.011	0.011	0.012
BCS	0.02	-0.03	0.08	
P-Value	0.911	0.819	0.526	
Breed	0.245	0.226	0.263	0.236
P-Value	0.0001	0.0001	0.0001	0.0001
Time(weeks of lactation)	-0.044	-0.047		
P-Value	0.042	0.032		
Age Yr.	-0.056			
P-Value	0.117			
S	0.735	0.737	0.741	0.741
R-Sq	0.22	0.21	0.20	0.20

Udder size: 1= Small; 2= Medium; 3 = Large. Udder attachment: 1= Well attached; 2= Hanging

BCS: 1.5, 2 and 3. Breed: 1= Indigenous; 2= Toggenburg; 3= British Alpine; 4= Saanen.

Age: 1= 1year; 2= 2years; 3= 4years.

Regression equations:

Full Model:

Equation 1: Milk (kg) = 0.48 +0.182 (udder size) + 0.37 (udder attachment) + 0.02 (BCS) + 0.245 (breed) – 0.044 time (weeks of lactation) – 0.056 (age)

Reduced Models:

Equation 2: Milk (ml) = 0.4165 + 0.23 udder size + 0.36 udder attachment - 0.03 (BCS) + 0.226 (breed) - 0.047 time (weeks of lactation)

Equation 3: Milk (ml) = -0.1701 + 0.235 (udder size) + 0.36 (udder attachment) + 0.08 (BCS) + 0.263 (breed)

Equation 4: Milk (ml) = 0.0998 + 0.232 (udder size) + 0.36 (udder attachment) + 0.236 (Breed)

The regression relations in Table 6.14 show that, although their relationship was weak ($r^2 = 22$), udder characteristics, breeds and lactation stage were significant as milk yield predictors. Age and BCS were not significant as predictors of milk yield. Therefore, in the exclusion of age, PTS can stand as a goat milkability predictor.

6.5 Conclusions

Based on the results obtained in this study, it is concluded that

- Age did not play any significant role either on milk or on blood parameters; its contribution as milk yield predictor was of 1% (table 6.14) and its level of confidence in milk characterization in goat was of 10% only (Table 6.1). For these reasons, age is discarded from the PTS.
- BCS, although a poor milk yield predictor (Table 6.14), was the strongest variable (54%) in milk characterization (Table 6.1); it remains in the PTS.
- Udder characteristics and breed can be used as milk yield predictor.
- PTS (BCS, breed and udder characteristics) is definitely a better tool than BCS in predicting milk yield in the lactating does. The weak relationship found in this study ($r^2 = 22$) is probably due to the small base (two months). Studies covering a longer observation period should improve this relationship.
- Cholesterol was an important (19%) variable in determining milk characterization in the lactating does (Table 6.1). The relationship of cholesterol to breed (Table 5.3), to BCS (Table 6.10) and to age in goats (Table 6.13) requires further investigation.

CHAPTER 7

General conclusions

This study has demonstrated that as a predictor of the lactating doe's milking ability, PTS is better than using BCS alone; further investigations are however needed to confirm the weak relationship found. Notwithstanding the above, using PTS will make a considerable impact in dairy goat farming because PTS is not only about making predictions on the goat's milkability, but also about feeding management, breed selection, herd management and crossbreeding programmes. A strategic application (and implication) of the PTS will help to take science-based decisions i) in fine-tuning feeding strategies that are specific to the animal metabolic demands and ii) in adopting the technical skills and farming practices which will result in farming high quality goats (as exemplified in picture 7.1) whose profitability will not be questionable contrarily to the current situation where African indigenous goats are seen as nuisance.

Picture 7.1: Using PTS system will result in farming quality goat than using BCS alone.



This on its own, will be a tremendous improvement in a farming business traditionally characterized by i) a lack of scientific skills and knowledge ii) a lack of facilities and technical equipment iii) a lack of public (financial) support services and iv) a lack of any clear cut technical strategies as to its raising procedures.

Phenotype scoring system is certainly not the ultimate solution to the dairy goat farming sector in Africa. It does however, propose a scientific approach in a farming system that has suffered much negligence in the past. Goat farming needs today much improvement in response to the African's increasing interest towards this farming area.

In this study, results obtained on does' milking capacity have shown unsurprisingly that dairy goat breeds yielded more milk quantitatively than did the Indigenous does. But milk from Indigenous does was higher in terms of milk protein, milk fat and lactose concentrations. This qualitative superiority of milk from Indigenous does is firstly, making them ideal for farmers interested in butter production; and secondly, it is crediting the indigenous goats as a potential asset for development since the industry pays premiums for fat and protein concentrations in milk.

The Indigenous goats have also revealed to be entirely under a homeostatic control during the production phase; they presented stability both in their milk constituents, their blood metabolites and their BCS during the entire period of investigation. This emphasizes their reputation of being a well established African genotype which can be exploited in diverse cross-breeding programmes.

Among the dairy breeds, the Toggenburg produced, under the provision of feed supplementation, more daily milk than the British Alpines and the Saanen. The British Alpines scored second in terms of milk yield and displayed its capacity to produce milk independently from the grazing quality and from feed supplementation strategies. In so doing, the Alpine demonstrated its exceptional adaptability capacity towards the African environmental conditions. As for the Saanen, they produced more milk than the Indigenous goats; but their dramatic BCS decline (Picture 7.2, next page), suggests and supports the view that in Africa, this breed cannot be used for milk exploitation without designing a properly balanced feed supplement. Saanen lactating does will do better in an intensive farming environment (which 90% of the African rural farmers are not yet familiar with at present). In an extensive farming system (as largely practiced nowadays in Africa) the African seasonal grass (degradability and availability) will depress the Saanen BCS and therefore its productive and reproductive capabilities.

The British Alpines is highly recommended for its exceptional capacity to produce independently from the grazing quality. In semi-intensive systems, with the provision of feed supplement, the Toggenburg can be exploited (as it is already the case in East-Africa) for milking operations especially since, in Africa, milk is sold as per volume basis and not for quality.



Figure 7.2: Saanen lost most BCS. BCS proved to be very sensitive to the availability of forages resources on rangeland (Santucci *et al.*, 1991).

Dairy goat farming promoted development in Europe and Asia. If properly managed, it can also enhance food security, job creation, income generation and lifestyle improvement in Africa.

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ADDENDUM: RAW DATA

WEEK	ANIMAL Number	PHENOTYPE CHARACTERISTICS					BLOOD ANALYSIS					MILK ANALYSIS				
		Breed	Ud. Size	Ud.Att.	AGE	BCS	Glucose	Cholest.	BUN	FFA	Yield	Lact.	Protein	Fat %	MUN	SCC
1	1	Indigenous	Medium	Well	4	3	2.3	2.33	6.3	0.0978	660	4.6	4.89	7.92	24.51	1325
1	2	Indigenous	Medium	Well	4	3	0.8	3.36	5.6	0.1998	600	4.71	4.86	4.51	24.51	389
1	3	Indigenous	Medium	Well	4	3	2	2.62	7.7	0.1621	960	5.11	3.74	6.7	16.32	374
1	4	Indigenous	Small	Well	4	3	1.5	2.05	5	0.1077	1020	4.88	4.22	5.34	22.41	595
1	5	Indigenous	Medium	Well	2	2.5	1.7	1.51	4.3	0.1971	1380	4.9	4.91	7.4	24.79	451
1	6	Indigenous	Medium	Well	1	3	1.9	*	6.5	0.1889	1140	5.42	4.03	6.39	18.27	1540
1	7	Indigenous	Medium	Well	1	3	1.1	1.82	6.8	0.1747	540	5.18	3.94	4.14	15.92	378
1	8	Indigenous	Small	Well	4	2.5	1.8	2.18	8	0.1157	840	4.76	3.25	10.86	27.41	204
1	1	Toggnburg	Medium	Well	4	2.5	1.8	2.12	3.8	0.1842	2520	4.63	2.52	5.5	9.9	2934
1	2	Toggnburg	Medium	Hang	4	2.5	2.1	2.1	4.9	0.1456	2640	4.78	2.32	6.62	11.98	3669
1	3	Toggnburg	Medium	Well	4	3	1.4	3.23	6	0.219	1200	4.68	2.52	5.32	15.46	3474
1	4	Toggnburg	Medium	Well	2	2.5	1.1	2.13	5.4	0.1374	1620	4.9	3.07	4.11	16.36	2211
1	5	Toggnburg	Medium	Well	1	3	1.1	2.56	4.6	0.1265	1920	4.61	1.98	3.75	5.71	2649
1	6	Toggnburg	Medium	Well	1	2.5	1.9	2.32	4.1	0.1472	2400	3.48	3.08	5.47	24.36	24126
1	7	Toggnburg	Medium	Well	1	2.5	2.9	2.13	5.3	0.2158	1128	3.83	3.42	11.88	22.33	20356
1	8	Toggnburg	Medium	Well	2	2.5	1.6	3.11	5.9	0.1774	1620	4.22	3.07	9.79	25.99	4493
1	1	B_Alpinen	Medium	Well	4	2.5	2.2	1.69	2.9	0.1882	1320	3.82	3.63	5.69	12.69	17773
1	2	B_Alpinen	Small	Well	4	2.5	0.7	3.02	5.9	0.2164	1680	3.58	3.71	11.68	26.35	6533
1	3	B_Alpinen	Medium	Well	4	2.5	2.4	2.37	3.1	0.6678	1800	3.51	3.42	8.68	29.04	18551
1	4	B_Alpinen	Medium	Well	4	2	1.2	2.12	4.2	0.2222	1200	4.66	3.11	8.08	25.72	6679
1	5	B_Alpinen	Large	Well	2	2.5	2.2	1.82	4.3	0.2095	1440	4.46	3.99	5.87	39.13	3744
1	6	B_Alpinen	Large	Hang	1	2	2.4	2.26	4.7	0.2361	1440	4.46	4.11	10.77	26.86	2235
1	7	B_Alpinen	Large	Hang	1	2	1.8	1.97	5.5	0.1764	1560	3.33	3.98	7.07	22.07	11350
1	8	B_Alpinen	Medium	Hang	4	2.5	1.7	1.73	4.4	0.1089	2280	4.54	2.72	5.83	15.37	1278
1	1	Saanen	Large	Well	4	2	1.2	2.91	4.8	0.2717	3000	3.93	3.21	8.32	22.99	4700
1	2	Saanen	Small	Well	4	2	2.1	2.02	5.2	0.2014	1320	2.95	5.04	11.76	24.32	24590
1	3	Saanen	Medium	Well	4	2	1.5	2.77	5.5	0.1425	1140	3.97	3.56	12.6	29.41	5212
1	4	Saanen	Medium	Well	4	2	1.6	2.64	4.8	0.1697	3120	3.29	4	11.74	21.81	29366
1	5	Saanen	Small	Well	2	2	2.2	2.47	5.3	0.1263	3000	4.9	2.98	6.34	19.64	425
1	6	Saanen	Large	Well	2	2	1.7	3.13	6.9	0.215	1560	3.91	2.61	9.97	22.87	7671
1	7	Saanen	Medium	Well	1	2	2.1	1.88	5.6	0.2098	2880	4.65	2.9	4.63	10.51	371
1	8	Saanen	Medium	Well	1	2.5	2	2.83	5.1	0.1058	1800	4.62	2.72	4.67	8.43	2101
2	1	Indigenous	Medium	Well	4	3	2.9	3.26	8.1	0.1976	384	3.78	3.92	7.15	28.87	6143
2	2	Indigenous	Medium	Well	4	3	3.2	3.84	7.2	0.2704	348	4.05	2.65	4.03	24.71	2789
2	3	Indigenous	Medium	Well	4	3	2.7	2.96	8.2	0.2158	648	4.45	3.3	7.85	25.15	3866
2	4	Indigenous	Small	Well	4	3	2.3	2.08	5.7	0.2819	540	3.8	3.2	5.06	17.14	9581
2	5	Indigenous	Medium	Well	2	2.5	3.4	2.01	4.9	0.363	1320	3.58	3.44	8.78	25.05	31774
2	6	Indigenous	Medium	Well	1	3	3.8	*	6.1	0.2342	1056	4.28	3.83	5.31	21.77	3427
2	7	Indigenous	Medium	Well	1	3	3.9	2.08	8.6	0.2997	768	4.08	3.5	6.28	18.29	17911
2	8	Indigenous	Small	Well	4	2.5	3.2	2.51	5.3	0.3457	456	4.04	3.47	6.45	27.48	4836
2	1	Toggnburg	Medium	Well	4	2.5	2.1	2.04	3	0.2283	1680	4.32	3.38	5.94	30.27	1665
2	2	Toggnburg	Medium	Hang	4	2.5	3.3	1.86	2.4	0.47	160	4.24	3.96	6.22	19.39	3931
2	3	Toggnburg	Medium	Well	4	3	1.6	2.45	4.5	0.2747	960	3.76	4.41	6	24.62	12673
2	4	Toggnburg	Medium	Well	2	2.5	2.3	2.17	4.7	0.2629	1920	1.82	5.48	7.65	19.68	31132



2	5	Toggburg	Medium	Well	1	3	1.2	2.7	2.5	0.2235	1800	4	3.24	4.38	28.12	7698
2	6	Toggburg	Medium	Well	1	3	1.9	2.04	3.7	0.2192	2160	2.1	5.92	8.17	24.25	15824
2	7	Toggburg	Medium	Well	1	2.5	3.4	2.22	4.8	0.2667	2640	3.42	3.61	8.06	20.5	23982
2	8	Toggburg	Medium	Well	2	2.5	2.1	2.47	4.6	0.2414	840	4.38	4.02	9.09	26.33	3300
2	1	B_Alpin	Medium	Well	4	2.5	0.6	1.7	4	0.2778	1560	4.51	5.05	12.57	40.55	917
2	2	B_Alpin	Small	Well	4	2.5	1.7	2.6	6.5	0.2963	1200	4.72	4.5	5.45	29.88	7515
2	3	B_Alpin	Medium	Well	4	2.5	3.4	1.95	4.9	0.3867	2400	5.23	4.08	5.8	30.11	323
2	4	B_Alpin	Medium	Well	4	2	1.9	2.19	6.5	0.3703	1800	4.68	4.76	6.23	33.24	1421
2	5	B_Alpin	Large	Well	2	2.5	3	1.78	4.5	0.1831	2280	4.98	3.86	5.6	22.5	898
2	6	B_Alpin	Large	Hang	1	2	3.2	2.54	5.3	0.3045	1680	4.97	4.71	6.23	28.8	693
2	7	B_Alpin	Large	Hang	1	2	2.4	1.49	4.7	0.1857	2280	4.48	4.43	5.57	25.15	2134
2	8	B_Alpin	Medium	Hang	4	2.5	1.7	1.49	5	0.2266	2040	4.73	4	6.79	28.84	348
2	1	Saenen	Large	Well	4	2	2.3	2.78	3.9	0.3118	1032	4.37	3.09	6.94	23.84	876
2	2	Saenen	Small	Well	4	2	2.6	2.17	3.2	0.3351	360	3.85	4.44	6.34	29.48	3948
2	3	Saenen	Medium	Well	4	2	2.4	2.81	3.8	0.2528	1164	4.3	3	6.17	25.61	3031
2	4	Saenen	Medium	Well	4	2	1.7	2.92	5.9	0.2633	2160	4	3.45	5.64	26.01	7754
2	5	Saenen	Small	Well	2	1.5	2.5	1.92	3.9	0.2576	1320	4.13	3.17	3.2	25.98	7609
2	6	Saenen	Large	Well	2	1.5	2.4	2.35	6.2	0.2733	1440	3.39	3.91	8.27	31.02	21534
2	7	Saenen	Medium	Well	1	2	2.2	1.95	3.2	0.3026	1032	4.32	3.61	7.64	27.53	12591
2	8	Saenen	Medium	Well	1	2	1.9	2.9	4.8	0.2774	4560	3.92	3.66	8.59	18.63	3980
3	1	Indigen	Medium	Well	4	2.5	1.3	2.28	4.5	0.5379	468	3.94	3.4	5.96	34.69	28425
3	2	Indigen	Medium	Well	4	3	0.9	2.32	7.4	1.0814	480	3.43	4.26	5.32	22.86	30896
3	3	Indigen	Medium	Well	4	3	2.8	2.22	3.2	0.4404	876	4.3	3.1	5.68	28.16	644
3	4	Indigen	Small	Well	4	3	2.2	2.14	3.9	0.443	588	3.89	2.96	3.6	25.48	14563
3	5	Indigen	Medium	Well	2	2	1.3	1.08	2.3	0.5332	1080	4.41	2.96	4.36	20.08	5111
3	6	Indigen	Medium	Well	1	3	3.1	*	7.4	1.3692	1080	4.51	3.45	4.62	17.19	3951
3	7	Indigen	Medium	Well	1	3	1.5	2.19	2.4	0.7356	372	3.81	3.19	2.96	25.13	22502
3	8	Indigen	Small	Well	4	2.5	2.6	2.34	7.2	0.9042	720	4.04	2.99	6.31	30.87	12102
3	1	Toggburg	Medium	Well	4	2.5	1	2.19	2.1	0.5357	2400	4.35	2.94	4.55	27.23	5999
3	2	Toggburg	Medium	Hang	4	2.5	2.6	1.93	2.1	0.8812	4200	4.37	1.92	3.36	25.4	3894
3	3	Toggburg	Medium	Well	4	3	1.3	3.76	7.6	0.5005	1500	4.5	3.07	3.75	26.51	9876
3	4	Toggburg	Medium	Well	2	2.5	0.5	1.68	8.2	0.6312	3000	4.09	2.44	4.51	18.37	8091
3	5	Toggburg	Medium	Well	1	3	0.5	2.17	2.5	0.6312	3120	4.32	2.82	5.27	21.18	5583
3	6	Toggburg	Medium	Well	1	2.5	1.5	1.96	4.3	0.9397	3480	3.8	3.17	5.59	21.2	30284
3	7	Toggburg	Medium	Well	1	2	2.6	1.78	3.7	1.2566	2160	4.45	3.06	4.1	29.39	1071
3	8	Toggburg	Medium	Well	2	2	1.1	1.54	2	0.7021	984	4.48	2.26	2.62	19.02	6404
3	1	B_Alpin	Medium	Well	4	2.5	0.2	1.86	3	1.0367	2640	4.67	4.94	4.53	29.77	2873
3	2	B_Alpin	Small	Well	4	2.5	0.4	2.77	7.2	1.5386	1440	5.21	4.05	3.88	29.02	259
3	3	B_Alpin	Medium	Well	4	2	1.1	2.45	8	1.082	3480	4.68	4.86	3.94	23.73	431
3	4	B_Alpin	Medium	Well	4	2	1	1.7	3.2	2.0154	2760	4.79	4.64	4.02	30.29	2639
3	5	B_Alpin	Large	Well	2	2.5	2.2	1.64	7.7	0.7719	1680	4.42	3.73	4.59	20.29	439
3	6	B_Alpin	Large	Hang	1	2	1.1	2.62	5.1	0.6263	4020	4.39	5.34	5.59	22.85	7102
3	7	B_Alpin	Large	Hang	1	2	0.4	2.16	6.3	1.1082	3120	4.82	3.79	6.81	23.96	736
3	8	B_Alpin	Medium	Hang	4	2.5	1.4	1.55	2.1	1.1107	1800	4.89	4.94	5	27.04	1842
3	1	Saenen	Large	Well	4	2	0.5	2.48	14.9	0.4943	2040	3.6	3.75	5.23	22.7	19547
3	2	Saenen	Small	Well	4	2	2.2	2.14	5.7	0.3842	1740	1.72	5.63	7.98	23.43	17472
3	3	Saenen	Medium	Well	4	2	0.4	3.06	9.7	0.7333	1800	4.9	3.26	5.9	25.31	9284
3	4	Saenen	Medium	Well	4	2	0.6	3.43	4	0.6478	2760	3.85	3.19	5.14	17.73	21688
3	5	Saenen	Small	Well	2	1.5	1.1	2.83	8.8	1.4485	1200	4.43	2.32	3.52	27.54	3863
3	6	Saenen	Large	Well	2	1.5	0.6	4.56	9.2	0.8641	1068	1.81	7.39	9.27	26.24	27430
3	7	Saenen	Medium	Well	1	2	2.1	2.31	8.1	1.2123	2040	3.74	3.97	5.93	20.56	29602



3	8	Saanen	Medium	Well	1	2	0.3	2.92	5.2	0.8355	1680	4.43	2.84	2.62	22.62	666
4	1	Indigenous	Medium	Well	4	2.5	2.4	2	5.7	0.2043	456	4.93	4.73	3.91	30.82	928
4	2	Indigenous	Medium	Well	4	3	3.3	1.34	7.1	0.457	660	3.67	5.85	5.98	20.58	22263
4	3	Indigenous	Medium	Well	4	3	2.4	1.88	6.3	0.4594	1044	5.06	4.1	5.29	28.17	601
4	4	Indigenous	Small	Well	4	3	1.5	2.19	6.4	0.4165	648	4.88	4.67	5.23	24.51	2113
4	5	Indigenous	Medium	Well	2	2	2.3	1.36	6.2	0.3312	888	5.05	4.65	4.68	27.3	1785
4	6	Indigenous	Medium	Well	1	3	2.7	*	6.8	0.5249	1200	5.2	3.9	3.84	17.63	315
4	7	Indigenous	Medium	Well	1	3	2.6	1.97	5.2	1.1684	420	4.39	4.26	5.64	15.81	17989
4	8	Indigenous	Small	Well	4	2.5	2.5	1.8	8	0.6405	1320	5.09	5.08	5.28	29.4	1564
4	1	Toggnburg	Medium	Well	4	2.5	1.1	1.93	6	1.0475	3000	4.61	2.39	3.46	15.33	2945
4	2	Toggnburg	Medium	Hang	4	2.5	1.2	1.96	7.4	1.2003	3480	4.26	2.02	2.9	21.6	2798
4	3	Toggnburg	Medium	Well	4	3	1.3	2.47	4.7	1.0002	*	*	*	*	*	8863
4	4	Toggnburg	Medium	Well	2	2.5	2.6	1.76	7.6	0.1568	2640	3.87	3.42	4.34	26.59	31385
4	5	Toggnburg	Medium	Well	1	3	0.7	2.18	6.8	0.8963	2280	4.41	3.74	4.54	28.23	5252
4	6	Toggnburg	Medium	Well	1	2.5	1.6	1.53	8.5	0.9888	3120	4.4	2.95	4.14	20.82	8755
4	7	Toggnburg	Medium	Well	1	2	2.8	1.84	6.4	0.4263	1800	4.68	2.74	3.82	18.42	4485
4	8	Toggnburg	Medium	Well	2	2	3.1	1.01	5.9	0.4391	1500	4.3	2.44	2.15	29.63	6422
4	1	B_Alpiners	Medium	Well	4	2.5	2.8	1.81	5.4	0.8126	3000	4.93	4.73	3.91	30.82	928
4	2	B_Alpiners	Small	Well	4	2.5	0.9	2.28	9.3	1.1593	2400	3.67	5.85	5.98	20.58	22263
4	3	B_Alpiners	Medium	Well	4	2	2.6	1.98	6.8	0.7847	2040	5.06	4.1	5.29	28.17	601
4	4	B_Alpiners	Medium	Well	4	2	2.3	1.48	6.3	1.1079	2400	4.88	4.67	5.23	24.51	2113
4	5	B_Alpiners	Large	Well	2	2.5	3	1.34	3.6	0.8249	2760	5.05	4.65	4.68	27.3	1785
4	6	B_Alpiners	Large	Hang	1	2	1.9	2.31	7.2	0.2766	1920	5.2	3.9	3.84	17.63	315
4	7	B_Alpiners	Large	Hang	1	2	2.4	1.69	5.8	0.7723	2520	4.39	4.26	5.64	15.81	17989
4	8	B_Alpiners	Medium	Hang	4	2.5	2	0.98	8.3	0.8095	1920	5.09	5.08	5.28	29.4	1564
4	1	Saanen	Large	Well	4	2	1.2	2.63	7.2	1.3642	3720	4.35	2.79	3.8	28.22	3620
4	2	Saanen	Small	Well	4	2	1	2.05	7.1	0.9379	1260	4.88	3.23	3.58	14.22	7481
4	3	Saanen	Medium	Well	4	2	1.4	2.57	6.5	1.1564	1380	3.7	4.21	6.26	18.22	28799
4	4	Saanen	Medium	Well	4	2	0.8	3.34	9.7	1.1833	2520	4.47	3.12	2.77	29.7	2824
4	5	Saanen	Small	Well	2	1.5	1.3	2.48	7.2	1.4668	1800	4.33	4.12	4.31	24.83	20946
4	6	Saanen	Large	Well	2	1.5	1.8	3.38	7.9	0.688	780	2.13	8.24	10.13	27	24699
4	7	Saanen	Medium	Well	1	2	2	1.86	5.6	0.9575	2520	4.24	2.94	4.28	19.88	11522
4	8	Saanen	Medium	Well	1	2	1.2	3.04	8.8	1.4169	1800	2.46	5.85	6.46	23.7	18068
5	1	Indigenous	Medium	Well	4	2.5	1.1	1.1	5.6	0.4511	840	4.28	4.47	11.4	*	*
5	2	Indigenous	Medium	Well	4	3	0.7	1.43	4.5	0.271	780	4.87	4.83	4.71	*	*
5	3	Indigenous	Medium	Well	4	3	0.4	2.17	7.1	0.3063	744	4.57	4.77	5.24	*	*
5	4	Indigenous	Small	Well	4	3	1.3	2.01	4.6	0.2743	480	5.04	3.85	5.5	*	*
5	5	Indigenous	Medium	Well	2	2	0.7	1.29	7.1	0.6299	1200	4.94	3.91	6.9	*	*
5	6	Indigenous	Medium	Well	1	3	1.9	*	7.3	0.9364	1560	4.81	4.46	4.32	*	*
5	7	Indigenous	Medium	Well	1	3	0.5	1.48	5.9	0.7848	732	4.67	4.26	6.68	*	*
5	8	Indigenous	Small	Well	4	2.5	2.1	1.27	8.9	0.4271	1032	5.26	4.67	5.12	*	*
5	1	Toggnburg	Medium	Well	4	2.5	0.9	1.68	7.1	0.6759	*	*	*	*	*	*
5	2	Toggnburg	Medium	Hang	4	2	2.4	2.21	9.6	0.6893	1800	3.61	2.74	3.91	*	*
5	3	Toggnburg	Medium	Well	4	2.5	0.6	1.65	8.6	0.2918	2280	3.67	2.59	3.47	*	*
5	4	Toggnburg	Medium	Well	2	2	0.6	1.73	7.5	0.3753	2760	3.81	3.09	5.02	*	*
5	5	Toggnburg	Medium	Well	1	2.5	0.5	1.79	8.1	0.3758	2400	4.35	3.08	3.96	*	*
5	6	Toggnburg	Medium	Well	1	2.5	1.2	1.49	8.1	0.3298	2760	3.98	3.16	3.82	*	*
5	7	Toggnburg	Medium	Well	1	1.5	2.1	1.51	5.6	0.2478	600	4.09	3.03	4.56	*	*
5	8	Toggnburg	Medium	Well	2	2	2.1	1.46	5.3	1.0197	1320	4.21	2.89	2.34	*	*
5	1	B_Alpiners	Medium	Well	4	2.5	1.2	2.42	4.7	0.3586	2400	4.39	2.64	3.55	*	*
5	2	B_Alpiners	Small	Well	4	2.5	0.5	3.14	7.7	0.3031	1200	3.52	4.23	6.25	*	*



1	3	B_Alpin	Medium	Well	4	2	1.5	2.91	12.9	0.3294	1560	4.22	3.1	3.87	*	*
5	4	B_Alpin	Medium	Well	4	2	1	2.2	7.4	0.422	1140	4.3	3.06	5.18	*	*
5	5	B_Alpin	Large	Well	2	2.5	0.7	1.64	5.3	0.9702	2160	4.57	2.68	3.16	*	*
5	6	B_Alpin	Large	Hang	1	2	0.6	3.12	8.9	0.4946	2640	4.09	2.94	4.82	*	*
5	7	B_Alpin	Large	Hang	1	2	2.3	2.7	8.6	0.2062	660	3.99	3.28	3.23	*	*
5	8	B_Alpin	Medium	Hang	4	2.5	1	1.93	7.4	0.8315	1440	4.09	2.84	2.79	*	*
5	1	Saanen	Large	Well	4	2	0.8	2.39	9.5	0.7283	2160	4.32	2.42	2.82	*	*
5	2	Saanen	Small	Well	4	2	0.3	1.61	5.7	0.4557	1680	4.06	3.34	5.39	*	*
5	3	Saanen	Medium	Well	4	2	0.6	2.09	9.4	0.6576	1440	3.9	3.93	5.44	*	*
5	4	Saanen	Medium	Well	4	2	1.1	2.7	7.9	0.4486	1680	4.52	3.05	2.27	*	*
5	5	Saanen	Small	Well	2	1.5	1.1	1.77	7.3	0.3801	1440	4.4	3.29	3.65	*	*
5	6	Saanen	Large	Well	2	1.5	1.2	2.92	7.4	0.5198	720	2.62	6.43	6.61	*	*
5	7	Saanen	Medium	Well	1	2	1.1	1.1	6.5	0.4654	1800	4.13	2.96	3.56	*	*
5	8	Saanen	Medium	Well	1	2	0.6	2.47	7.5	0.6255	852	1.97	5.09	5.61	*	*
5	1	Indigen	Medium	Well	4	2.5	1.1	2.96	9	0.2068	456	4.42	2.81	3.42	39.84	5777
5	2	Indigen	Medium	Well	4	3	0.7	1.97	7.1	0.2925	300	4.95	4.59	5.95	44.21	1545
5	3	Indigen	Medium	Well	4	3	0.8	1.85	8.1	0.2516	828	4.58	3.82	4.02	26.83	824
5	4	Indigen	Small	Well	4	3	0.6	2.01	6.4	0.0833	192	5.12	3.86	4.57	42.8	628
5	5	Indigen	Medium	Well	2	2	1.1	1.48	7	0.2309	1140	4.99	4.4	2.98	36.44	638
5	6	Indigen	Medium	Well	1	3	1.8	*	10	0.297	960	4.19	5.53	7.28	34.99	4494
5	7	Indigen	Medium	Well	1	3	1.4	1.87	6.3	0.1916	240	4.93	3.8	5.21	34.37	1814
5	8	Indigen	Small	Well	4	2.5	1.4	2.62	10	0.249	960	4.77	4.21	5.17	38.24	2706
5	1	Toggnbu	Medium	Well	4	2.5	1.7	3.06	7.2	0.4083	1920	*	*	*	*	*
5	2	Toggnbu	Medium	Hang	4	2	1	2.24	8.3	0.2962	2280	4.29	2.51	2.01	24.97	17102
5	3	Toggnbu	Medium	Well	4	2.5	*	*	*	*	*	*	*	*	*	*
5	4	Toggnbu	Medium	Well	2	2	0.8	2.34	7.2	0.6066	1920	4.14	2.69	2.09	29.02	27809
5	5	Toggnbu	Medium	Well	1	2.5	0.4	2.91	10.1	0.4463	1320	4.02	2.94	3.07	34.57	1719
5	6	Toggnbu	Medium	Well	1	2.5	0.9	2.68	10.8	0.1966	3240	4.49	2.96	1.92	33.82	9596
5	7	Toggnbu	Medium	Well	1	1.5	1.7	2.64	8.3	0.3888	1320	4.26	2.94	3.74	23.79	11051
5	8	Toggnbu	Medium	Well	2	2	1	1.49	8.4	0.7939	1200	3.98	2.24	2.15	31.28	13682
5	1	B_Alpin	Medium	Well	4	2.5	1.5	2.25	11	0.3357	2520	3.71	2.39	2.72	19.16	9604
5	2	B_Alpin	Small	Well	4	2.5	0.8	2.9	12.1	0.35	1200	4.05	3.13	1.93	37.91	18969
5	3	B_Alpin	Medium	Well	4	2.5	1.6	2.08	13.3	0.3065	1320	4.16	3.2	3.55	27.49	15411
5	4	B_Alpin	Medium	Well	4	2	0.9	2.87	7.6	0.3764	1440	4.17	2.73	3.87	34.09	16649
5	5	B_Alpin	Large	Well	2	2.5	1.3	*	6	0.4615	2400	4.67	2.53	3.08	22	4263
5	6	B_Alpin	Large	Hang	1	2	1.3	2.5	9.2	0.6158	2520	4.5	2.8	4.21	26.36	2685
5	7	B_Alpin	Large	Hang	1	2	1	3.28	6.7	0.4557	1680	3.57	3.4	2.99	49.16	25742
5	8	B_Alpin	Medium	Hang	4	2.5	0.7	2.98	9.2	0.2828	1500	4.55	3.03	3.42	36.08	9525
5	1	Saanen	Large	Well	4	2	0.7	2.68	10	0.4324	1560	1.63	2.42	7.26	47.89	*
5	2	Saanen	Small	Well	4	2	0.4	1.88	8.8	0.7104	1440	4.31	3.34	2.39	27.85	11809
5	3	Saanen	Medium	Well	4	2	1	3.37	5.8	0.631	1320	2.21	3.93	6.9	28.09	22128
5	4	Saanen	Medium	Well	4	2	0.9	2.67	8.8	0.3419	2400	4.45	3.05	3.45	31.19	14865
5	5	Saanen	Small	Well	2	1.5	1.1	3.07	9.8	0.425	1008	5.54	3.29	1.86	32.76	3559
5	6	Saanen	Large	Well	2	1.5	2.6	3.06	6.7	0.424	240	4.08	6.43	4.09	23.55	26513
5	7	Saanen	Medium	Well	1	2	0.8	2.26	10.2	0.5783	2400	4.43	2.96	3.47	27.1	18728
5	8	Saanen	Medium	Well	1	2	*	2.41	13.4	0.7254	324	4.37	5.09	2.28	32.43	8866
6	1	Indigen	Medium	Well	4	3	1.6	2.11	10.6	0.4899	564	4.36	4.06	7.18	30.65	4513
6	2	Indigen	Medium	Well	4	3	2.3	1.61	6.5	0.48	528	4.85	4.24	4.47	27.19	2339
6	3	Indigen	Medium	Well	4	3	2.1	1.63	5.8	0.3281	1320	4.97	3.76	6.54	29.51	1699
6	4	Indigen	Small	Well	4	3	2.6	1.71	6.9	0.2288	360	4.58	5.29	5.3	29.83	5138
6	5	Indigen	Medium	Well	2	3	3.4	1.57	6.5	0.4986	1360	4.87	4.42	3.81	32.95	958



6	6	Indigenous	Medium	Well	1	3	4.7	*	7.1	0.5531	684	4.83	3.99	6.06	36.64	2638
6	7	Indigenous	Medium	Well	1	3	2.8	1.73	9.6	0.7796	432	4.7	4.38	7.18	36.6	3170
6	8	Indigenous	Small	Well	4	2.5	2.9	2.16	8.5	0.8305	852	4.45	4.55	8.06	35.55	2239
6	1	Toggnburg	Medium	Well	4	2.5	1.9	2.38	5.6	0.2045	1920	2.63	*	*	*	*
6	2	Toggnburg	Medium	Hang	4	2	1.6	2.39	9	0.3885	2040	4.49	*	*	*	*
6	3	Toggnburg	Medium	Well	4	2.5	*	*	*	*	*	*	2.51	2.61	22.15	17102
6	4	Toggnburg	Medium	Well	2	2	0.8	2.69	6.7	0.656	1626	4.36	2.69	5.08	28.6	14814
6	5	Toggnburg	Medium	Well	1	2.5	0.8	3.94	5.7	0.3023	1380	4.16	2.94	2.71	28.24	27809
6	6	Toggnburg	Medium	Well	1	2.5	3.1	1.98	10.5	0.186	1560	3.7	2.96	4.51	26.26	1719
6	7	Toggnburg	Medium	Well	1	1.5	0.2	3.4	7.1	0.4141	1188	4.18	2.94	3.56	26.18	9596
6	8	Toggnburg	Medium	Well	2	2	2	2.17	5.2	0.652	1680	3.92	2.24	2.18	29.47	11051
6	1	B_Alpin	Medium	Well	4	2.5	3.5	1.68	9.4	0.2676	1800	4.24	2.77	3.87	35.31	7997
6	2	B_Alpin	Small	Well	4	2	2.3	2.36	11.2	0.3921	1320	4.4	3.33	4.03	28.27	6986
6	3	B_Alpin	Medium	Well	4	2	2.7	1.83	11.8	0.2185	1200	3.32	3.8	3.92	39.32	28324
6	4	B_Alpin	Medium	Well	4	2	3.5	1.2	6	0.4311	1500	4.5	3.35	3.23	27.53	2723
6	5	B_Alpin	Large	Well	2	1.5	2.4	0.85	4.8	0.4634	1800	4.47	2.64	3.05	25.26	5926
6	6	B_Alpin	Large	Hang	1	2	2	1.87	7.6	0.4044	2520	3.94	3.09	3.89	29.65	25915
6	7	B_Alpin	Large	Hang	1	2	0.7	1.45	7.6	0.5445	2040	3.89	3.43	4.36	25.14	26082
6	8	B_Alpin	Medium	Hang	4	2.5	3	1.19	10.2	0.3612	1560	3.59	3.13	2.95	25.17	20339
6	1	Saenen	Large	Well	4	2	1.9	2.63	9.7	0.251	*	*	*	*	*	*
6	2	Saenen	Small	Well	4	2	1.7	2.35	3.2	0.7034	1260	4.07	2.62	2.49	35.22	9227
6	3	Saenen	Medium	Well	4	2	1.7	4.03	7.7	0.3334	1500	4.36	2.82	3.22	14.93	11378
6	4	Saenen	Medium	Well	4	2	2.7	2.95	9.5	0.2365	1200	4.47	2.93	4.19	23.23	8413
6	5	Saenen	Small	Well	2	1.5	2.5	3.52	7.3	0.4092	1500	4.17	2.92	1.63	35.88	3698
6	6	Saenen	Large	Well	2	1.5	1.9	3.36	9.6	0.351	1440	4.2	3.07	4.51	25.74	18635
6	7	Saenen	Medium	Well	1	1.5	3.9	2.87	7.3	0.1946	192	3.14	5.43	4.46	32	27323
6	8	Saenen	Medium	Well	1	2	*	*	*	*	1500	4.23	2.8	2.95	32.03	14851
7	1	Indigenous	Medium	Well	4	3	*	*	*	*	880	3.58	3.44	8.78	25.05	31774
7	2	Indigenous	Medium	Well	4	3	*	*	*	*	348	4.05	2.65	4.03	24.71	2789
7	3	Indigenous	Medium	Well	4	3	*	*	*	*	456	4.04	3.47	6.45	27.48	4836
7	4	Indigenous	Small	Well	4	3	*	*	*	*	360	3.8	3.2	5.06	17.14	9581
7	5	Indigenous	Medium	Well	2	2.5	*	*	*	*	1056	4.28	3.83	5.31	21.77	3427
7	6	Indigenous	Medium	Well	1	3	*	*	*	*	768	4.08	3.5	6.28	18.29	17911
7	7	Indigenous	Medium	Well	1	3	*	*	*	*	648	4.45	3.3	7.85	25.15	3866
7	8	Indigenous	Small	Well	4	2.5	*	*	*	*	384	3.78	3.92	7.15	28.87	6143
7	1	Toggnburg	Medium	Well	4	2.5	*	*	*	*	1680	*	*	*	*	*
7	2	Toggnburg	Medium	Hang	4	2	*	*	*	*	1800	4	3.24	5.94	28.12	7698
7	3	Toggnburg	Medium	Well	4	2	*	*	*	*	840	4.38	4.02	9.09	26.33	3300
7	4	Toggnburg	Medium	Well	2	1.5	*	*	*	*	2160	2.1	5.92	8.17	24.25	15824
7	5	Toggnburg	Medium	Well	1	2.5	*	*	*	*	1920	1.82	5.48	7.65	19.68	31132
7	6	Toggnburg	Medium	Well	1	2	*	*	*	*	960	3.76	4.41	6	24.62	12673
7	7	Toggnburg	Medium	Well	1	2	*	*	*	*	2640	3.42	3.61	8.06	20.5	23982
7	8	Toggnburg	Medium	Well	2	1.5	*	*	*	*	2160	4.24	3.96	6.22	19.39	3931
7	1	B_Alpin	Medium	Well	4	2	*	*	*	*	2280	4.98	3.86	5.6	22.5	898
7	2	B_Alpin	Small	Well	4	1.5	*	*	*	*	1680	4.97	4.71	6.23	28.8	693
7	3	B_Alpin	Medium	Well	4	2	*	*	*	*	1800	4.68	4.76	6.23	33.24	1421
7	4	B_Alpin	Medium	Well	4	2	*	*	*	*	2040	4.73	4	6.79	28.84	348
7	5	B_Alpin	Large	Well	2	1.5	*	*	*	*	2280	4.48	4.43	5.57	25.15	2134
7	6	B_Alpin	Large	Hang	1	2	*	*	*	*	2400	5.23	4.08	5.8	30.11	323
7	7	B_Alpin	Large	Hang	1	1.5	*	*	*	*	1560	4.51	5.05	12.57	40.55	917
7	8	B_Alpin	Medium	Hang	4	2	*	*	*	*	1200	4.72	4.5	5.45	29.88	7515



7	1	Saanen	Large	Well	4	1.5	*	*	*	*	1032	4.32	3.61	7.64	27.53	12591
7	2	Saanen	Small	Well	4	1.5	*	*	*	*	360	3.85	4.44	6.34	29.48	3948
7	3	Saanen	Medium	Well	4	2	*	*	*	*	1032	4.37	3.09	6.94	23.84	876
7	4	Saanen	Medium	Well	4	2	*	*	*	*	3040	3.92	3.66	8.59	18.63	3980
7	5	Saanen	Small	Well	2	1.5	*	*	*	*	1320	4.13	3.17	3.2	25.98	7609
7	6	Saanen	Large	Well	2	1.5	*	*	*	*	1164	4.3	3	6.17	25.98	3031
7	7	Saanen	Medium	Well	1	1.5	*	*	*	*	2160	4	3.45	5.64	25.61	7754
7	8	Saanen	Medium	Well	1	1.5	*	*	*	*	1440	3.39	3.91	8.27	26.01	21534
8	1	Indigenous	Medium	Well	4	3	*	*	*	*	880	3.58	3.44	8.78	25.05	31774
8	2	Indigenous	Medium	Well	4	3	*	*	*	*	348	4.05	2.65	4.03	24.71	2789
8	3	Indigenous	Medium	Well	4	3	*	*	*	*	456	4.04	3.47	6.45	27.48	4836
8	4	Indigenous	Small	Well	4	3	*	*	*	*	360	3.8	3.2	5.06	17.14	9581
8	5	Indigenous	Medium	Well	2	2.5	*	*	*	*	1056	4.28	3.83	5.31	21.77	3427
8	6	Indigenous	Medium	Well	1	3	*	*	*	*	768	4.08	3.5	6.28	18.29	17911
8	7	Indigenous	Medium	Well	1	3	*	*	*	*	648	4.45	3.3	7.85	25.15	3866
8	8	Indigenous	Small	Well	4	2.5	*	*	*	*	384	3.78	3.92	7.15	28.87	6143
8	1	Toggnburg	Medium	Well	4	2.5	*	*	*	*	1680	*	*	*	*	*
8	2	Toggnburg	Medium	Hang	4	2	*	*	*	*	1800	4	3.24	5.94	28.12	7698
8	3	Toggnburg	Medium	Well	4	2	*	*	*	*	840	4.38	4.02	9.09	26.33	3300
8	4	Toggnburg	Medium	Well	2	1.5	*	*	*	*	2160	2.1	5.92	8.17	24.25	15824
8	5	Toggnburg	Medium	Well	1	2.5	*	*	*	*	1920	1.82	5.48	7.65	19.68	31132
8	6	Toggnburg	Medium	Well	1	2	*	*	*	*	960	3.76	4.41	6	24.62	12673
8	7	Toggnburg	Medium	Well	1	2	*	*	*	*	2640	3.42	3.61	8.06	20.5	23982
8	8	Toggnburg	Medium	Well	2	1.5	*	*	*	*	2160	4.24	3.96	6.22	19.39	3931
8	1	B_Alpiners	Medium	Well	4	2	*	*	*	*	2280	4.98	3.86	5.6	22.5	898
8	2	B_Alpiners	Small	Well	4	1.5	*	*	*	*	1680	4.97	4.71	6.23	28.8	693
8	3	B_Alpiners	Medium	Well	4	2	*	*	*	*	1800	4.68	4.76	6.23	33.24	1421
8	4	B_Alpiners	Medium	Well	4	2	*	*	*	*	2040	4.73	4	6.79	28.84	348
8	5	B_Alpiners	Large	Well	2	1.5	*	*	*	*	2280	4.48	4.43	5.57	25.15	2134
8	6	B_Alpiners	Large	Hang	1	2	*	*	*	*	2400	5.23	4.08	5.8	30.11	323
8	7	B_Alpiners	Large	Hang	1	1.5	*	*	*	*	1560	4.51	5.05	12.57	40.55	917
8	8	B_Alpiners	Medium	Hang	4	2	*	*	*	*	1200	4.72	4.5	5.45	29.88	7515
8	1	Saanen	Large	Well	4	1.5	*	*	*	*	1032	4.32	3.61	7.64	27.53	12591
8	2	Saanen	Small	Well	4	1.5	*	*	*	*	360	3.85	4.44	6.34	29.48	3948
8	3	Saanen	Medium	Well	4	2	*	*	*	*	1032	4.37	3.09	6.94	23.84	876
8	4	Saanen	Medium	Well	4	2	*	*	*	*	3040	3.92	3.66	8.59	18.63	3980
8	5	Saanen	Small	Well	2	1.5	*	*	*	*	1320	4.13	3.17	3.2	25.98	7609
8	6	Saanen	Large	Well	2	1.5	*	*	*	*	1164	4.3	3	6.17	25.98	3031
8	7	Saanen	Medium	Well	1	1.5	*	*	*	*	2160	4	3.45	5.64	25.61	7754
8	8	Saanen	Medium	Well	1	1.5	*	*	*	*	1440	3.39	3.91	8.27	26.01	21534

