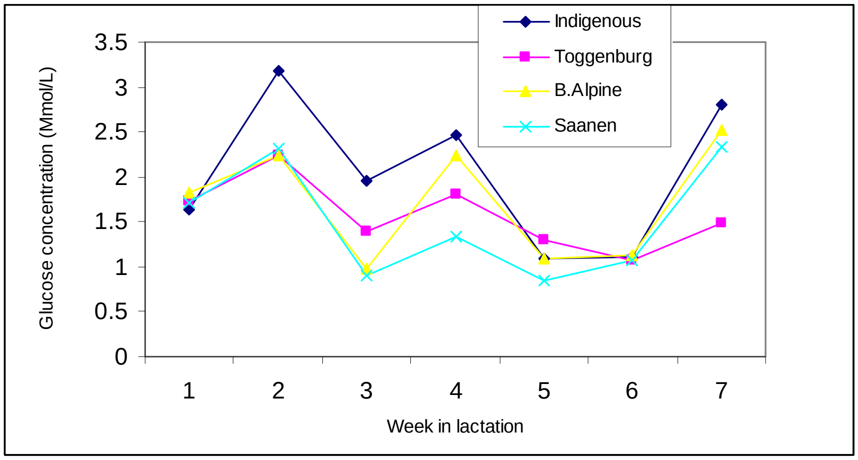
CHAPTER 5

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 (± 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 ± 0.90^{a}
Indigenous	56	2.0 ± 0.97^{b}
Saanen	54	1.5 ± 0.77^{a}
Toggenburg	54	1.6 ± 0.81^{a}
p/value		0.001
Coeff/variation		34.544
LSD		0.3973

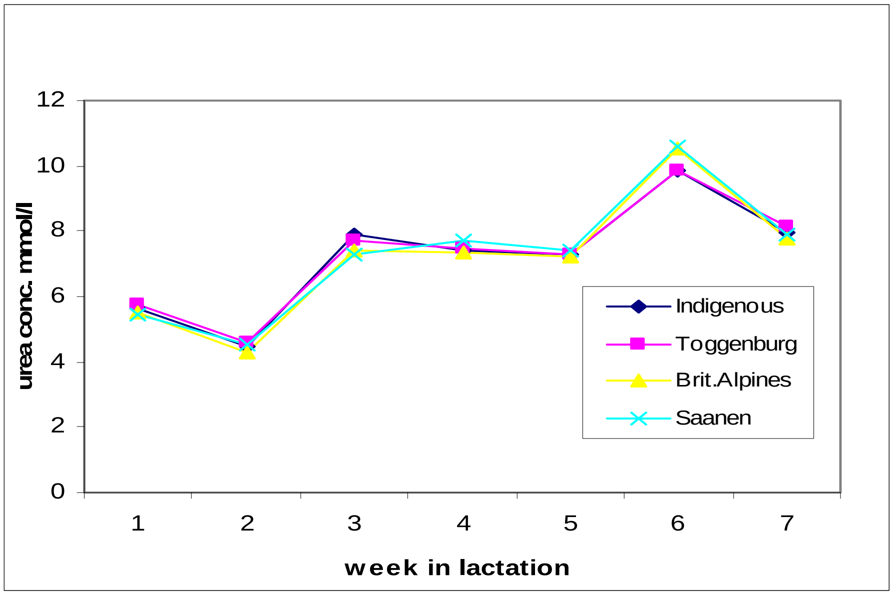
Means per column with different superscript ($^{a\ b}$) letters differed significantly ($p \leq 0.001$)
n = number of observations.

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.



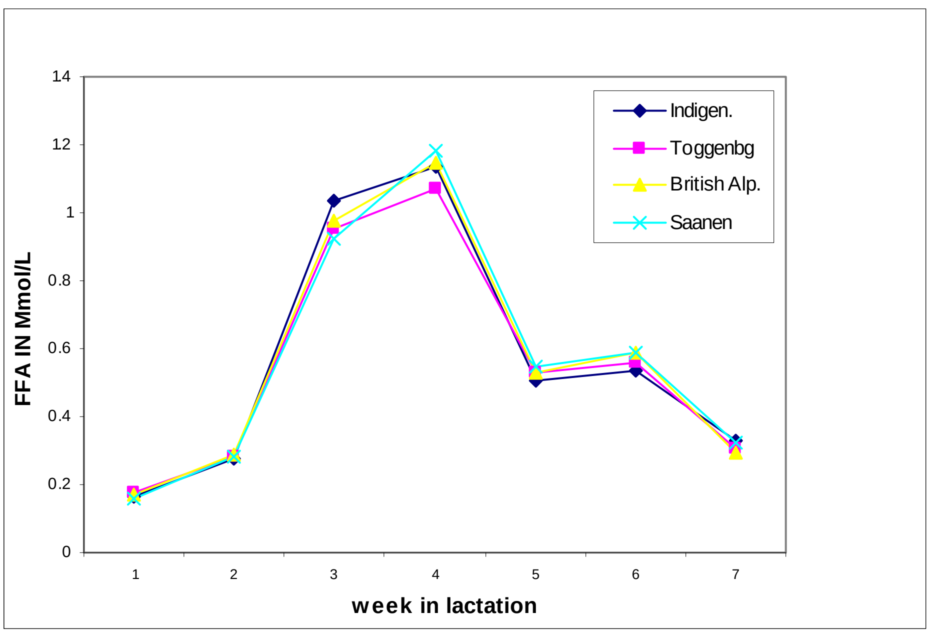
Graph 5.2: BUN concentrations of Indigenous and dairy breeds during the first seven weeks of lactation.

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% N_2, 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 (±SD) blood FFA concentrations from different breed of does during the first eight weeks of lactation

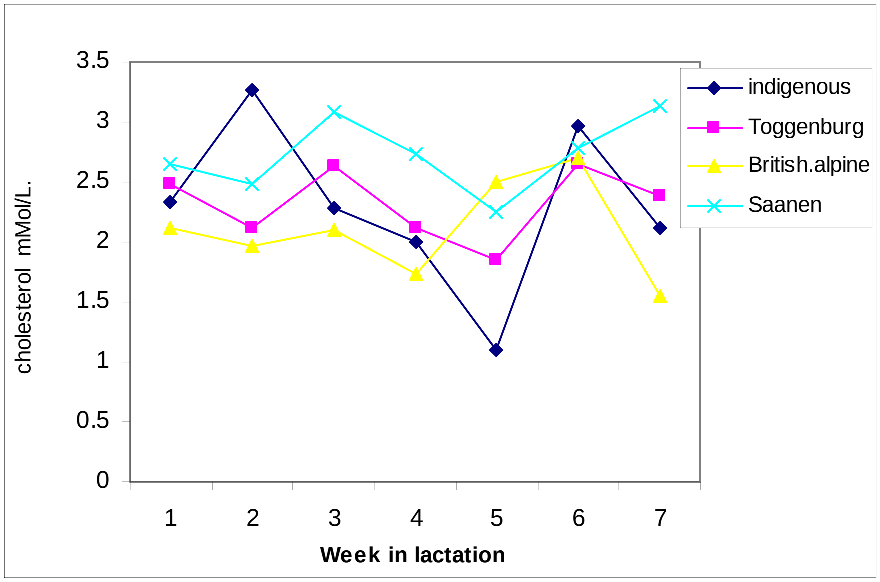
BREEDS	N	FFA (Mmol/L)
B. Alpine	56	0.5 ± 0.38^{a}
Indigenous	56	0.4 ± 0.28^{b}
Saanen	55	0.5 ± 0.37^{a}
Toggenburg	54	0.5 ± 0.30^{a}
p-value		0.001
Coeff/variation		43.1663
LSD		0.0935

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 (±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 ± 0.11 [ac]	6.96 ± 0.34	1.6 ±0.07
Indigenous	1.6 ±0.25	1.5 ± 0.16 [b]	6.04 ± 0.50	0.4 ± 0.10
Saanen	1.6 ±0.12	2.7 ± 0.08 [a]	7.19 ±0.24	0.5 ±0.05
Toggenburg	1.7 ± 0.14	2.3 ± 0.09 [c]	6.09 ± 0.29	0.5 ±0.55
p-value	0.492	p≤ 0.01	0.010	0.3

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

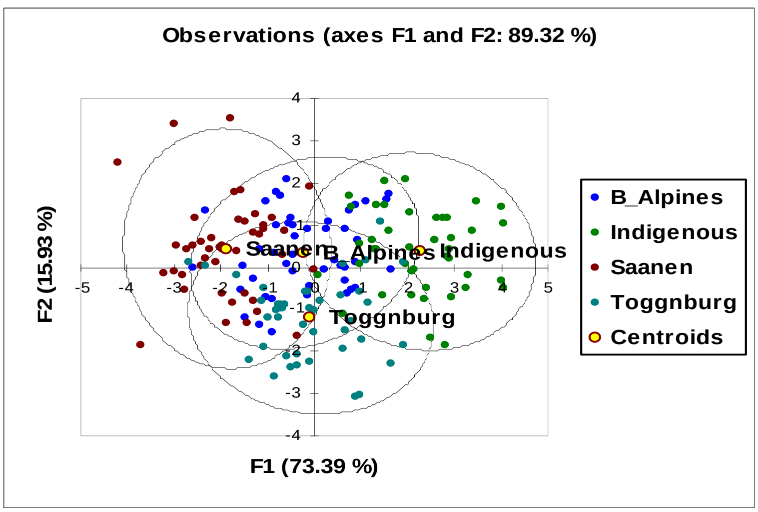
Table 5.3 showing blood cholesterol as the unique blood metabolite on which breed is having an effect may be a way to underline the importance of cholesterol in the goat milk characterization.

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 (±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 ± 0.4 ^{b}	3.8 ± 0.1 ^{b}	3.5 ± 0.3 ^{ab}	27.9 ±1.2	13690 ±18	1463 ± 14
* 2.5	4.3 ± 0.4 ^{a}	4.4 ± 0.1 ^{b}	4.3 ± 0.3 ^{a}	9.7 ±1.1	8246 ±15	1667 ± 12
* 3.	6.2 ± 0.3 ^{b}	4.2 ± 0.1 ^{b}	5.1 ± 0.2 ^{ac}	24.2 ±0.1	8885 ±13	631 ± 10
p-value	p≤0.05	p≤ 0.01	p≤0.02	0.011	0.014	1.000

Mean per column followed by a different superscript letters do significantly (p≤ 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.

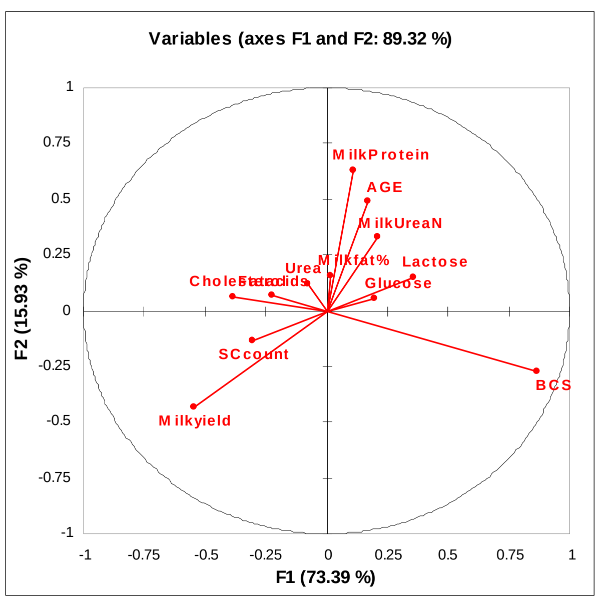
Does. BCS	n	Milk yield(ml) Mean+ Std Dev
1.5	28	1300 ± 56 ^{a}
2	95	1870.147 ± 81 ^{b}
2.5	75	1821.973 ± 83 ^{b}
3	53	877.283 ± 58 ^{c}
p-value		0.001
R-square		0.496539
Coefficient/Variation		43.15020

Mean per column followed by different superscript ($^{a\ b}$) letters differed significantly (p ≤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 (±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 ± 0.38	3.87 ± 0.13	5.5 ± 0.30 ^{ab}	28.03 ± 1.16	10873 ±1641.	1863 ±128.1 ^{a}
Medium	5.020 ±0.17	4.09 ± 0.06	4.02 ±0.13 ^{ac}	26.0 ± 0.52	9724.5 ±737.7	1695 ±57.5 ^{b}
Small	5.395 ± 0.35	4.4 ± 0.12	4.70 ± 0.30 ^{a}	27.4 ±1.06	7205.4 ±1498	1243^{c} ±117
p-value	0.189	0.02	p≤0.01	0.175	0.236	p≤ 0.01

Mean per column followed by a different superscripts (^{a,b,c}) letters did significantly(P≤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 ≤0.001)
n= number of observations

In Table 6.5 it appears that milk yield does significantly differ (p ≤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 (±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 ±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 ±166 [b]
*** Medium**	4.591 ±0.76	4.064 ± 0.25	4.201 ± 0.60	27.003 ±2.3	8513.2 ±32559	1802.5 ±251[ab]
p-value	0,521	0.625	0.404	0.693	0.330	p≤ 0.01

Mean per column followed by a different superscript letters ([a,b,ab]) do significantly (p≤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+ Std Dev
Hanging	32	208.4 ± 838[a]
Well attached	219	151.1 ± 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≤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 (±SEM) milk yield and constituents of different breeds of goats.

VARIABLES	Fat (%)	Lactose(%)	Protein (%)	MUN (Mmol/L)	SCC (x1000)	M. Yield (ml)
AGE (Yrs)						
* 1	5.263 ±0.302	4.276 ±0.102	4.03 ±0.235	26.891 ±0.92	8631.6 ±1302	1529.9 ±101.6
* 2	5.24 ±0.289	4.091 ± 0.097	4.66 ±0.255	26.598 ±0.88	10287 ±1244	1719.3 ±97.03
* 4	5.23 ±0.213	4.026 ±0.072	4.59 ±0.166	26.671 ±0.65	9189.4 ±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 ± 02^{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	$p \leq 0.05$	$p \leq 0.01$	$p \leq 0.05$	0.359

Mean per column followed by a different letter were significantly ($P \leq 0.05$) 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 (±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 ± 0,01[a]	7.291 ± 0.34	0.596 ±0.07
* Medium	1..727 ±0.07	2.189 ±0.05 [a]	6.392 ±0.32	0.509 ± 0.03
* Small	1.539 ±0.16	2.753 ± 0.10[b]	6.718 ± 0.27	0.5 ± 0.06
p-value	0.435	p≤0.01	0.044	0.967

Mean per column followed by different superscript ([a,b]) letters do significantly (P ≤ 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 (±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 (±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 ± 0.14	1.963 ± 0.08	6.492 ± 0.27	0.525 ±0.06
*** 2**	1..938 ± 0.13	2.535 ± 0.08	6.729 ±0.26	0.499 ±0.05
*** 4**	1.517 ± 0.01	2.28 ±0.06	6.681 ±0.20	0.492 ±0.04
p-value	0.026	0.01	0.811	0.897

Mean per column followed by a different letter do significantly (P ≤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 <u>a potential asset for development</u> 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 <u>which can be exploited in diverse cross-breeding programmes.</u>

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 exploitated (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.