An evaluation of the use of blood metabolite concentrations as indicators of nutritional status in free-ranging indigenous goats

R. Pambu-Gollah, P.B. Cronjé[#] and N.H. Casey
Department of Animal and Wildlife Science, University of Pretoria, Pretoria 0002, South Africa

Abstract

The aim of this study was to determine whether blood metabolite concentrations in free-ranging indigenous goats are sensitive to expected variations in nutrient supply, and whether they could be used to evaluate different kidding seasons at two locations subject to similar seasonal variations in terms of nutrient supply. Monthly blood samples were taken over a period of one year. At Delftzyl farm, where a winter kidding season (June) was practised, glucose concentrations decreased from February onwards and reached their lowest levels just prior to the kidding season. Plasma glucose concentrations increased sharply after parturition and subsequently decreased until the end of lactation. Glucose concentrations were lower in lactating does than in non-lactating does during the first two months of lactation. In contrast, glucose concentrations during lactation in does at Loskop farm, where kidding took place during spring (October), did not differ from those recorded during the four months following weaning, and neither were there differences between lactating and non-lactating does. Glucose concentrations during lactation at Loskop farm were also higher than at Delftzyl farm. The different responses can be attributed to the fact that lactation at Loskop farm coincided with peak nutrient availability during the summer period of vegetative growth, whereas lactation at Delftzyl farm coincided with low nutrient availability and quality during the winter period of plant dormancy. Plasma urea concentrations were also elevated during the last month of pregnancy and the first two months of lactation at this location, and were higher during lactation than those recorded at the summer kidding site, indicating that body protein reserves may have been catabolized to support gluconeogenesis in these animals. Plasma cholesterol concentrations were higher in lactating goats than in non-lactating goats at Delftzyl farm but not at Loskop farm. Cholesterol concentrations during lactation were also higher at Delftzyl than at Loskop. This suggests that body adipose tissue reserves were catabolized during the winter lactation at Delftzyl farm. These results indicate that lactating does at Delftzyl farm were unable to maintain glucose homeostasis during pregnancy and lactation without significant catabolism of body reserves, and suggests that the winter kidding practised there was inappropriate in relation to the available nutrient supply. It was concluded that the plasma concentrations of all the blood metabolites studied were sensitive to seasonal changes in nutrient supply, and that they could be of use as a management tool in free-ranging farming systems in which conventional methods of nutritional assessment are difficult to apply.

Keywords: Goats, nutrition, ruminant, glucose, urea, cholesterol, lactation
[#]Author to whom correspondence should be addressed; E-mail: pbcronje@postino.up.ac.za

Introduction

A need exists for a measure with which management strategies such as choice of kidding season can be evaluated under extensive and communal farming conditions. Under farming conditions where a relatively constant nutrient supply is available, such as in the case of irrigated homogenous pastures, alternative management strategies can be evaluated using standard tables (e.g. NRC, 1981) which enable the nutrient content of alternative pastures to be compared with the nutrient requirements of animals of different physiological states. In extensive farming systems, such as those described in this study, there is considerable variation in the nutritive value of natural pastures, as grass species enter a dormant period and deciduous trees shed their foliage during the winter months. This variation in both the quantity and quality of available nutrients, together with the fact that it is difficult to estimate the intake of the many browse species available to goats, make the estimation of nutrient intake difficult under these circumstances. Furthermore, the nutrient requirements of the indigenous South African goat have not been quantified. Body mass changes are not reliable as an index of nutrient status unless it is known which animals are pregnant and which are not and, even then, is complicated by the possibility of single, twin or triplet foetuses in pregnant animals. In addition, few farmers in communal systems have access to weighing facilities. Body condition scoring gives a better indication of nutritional status, but suffers from the disadvantage that quantifiable changes on a subjective five-point scale are observed too slowly to be used as an index on which to base preventative measures. Blood metabolite concentrations represent an integrated index of the adequacy of nutrient supply in relation to nutrient utilization that is independent of physiological state and give an immediate indication of nutritional status at that point in time (Cronjé & Pambu-Gollah, 1996). Metabolic profile tests are reported to have been used with success to evaluate the nutritional adequacy of diets fed to high-producing dairy cows during lactation (Payne, 1978), and

the concentrations of certain blood metabolites have been used to determine the supplementary energy requirements of ewes during pregnancy (Russel, 1985). The application of these techniques to evaluate the nutritional status of free-ranging animals in extensive and communal small-farmer animal production systems could have a substantial impact on management and development strategies. The aim of this study was to determine whether blood metabolite concentrations in free-ranging indigenous goats are sensitive to expected variations in nutrient supply, and whether they could be used to evaluate different kidding seasons at two locations subject to similar seasonal variations in terms of nutrient supply.

Materials and methods

Two flocks of free-ranging indigenous goat does were used in this study. These flocks are situated at Delftzyl Farm ($24^0$35' S; $29^0$14'E) and at Loskop South Farm (25^o18'S; 29^o21'E) in the north-eastern region of South Africa. Although the climate and type of animal at both locations were similar, the management systems differed: does kidded during winter (June) at Delftzyl farm and during the spring (October) at Loskop farm. Kids were weaned at 3 months of age at both locations. Animals at both sites grazed natural pastures during the day and were penned during the night due to the presence of predators. At Delftzyl farm, 21 does aged 1.5-3 years were sampled, and at Loskop farm 31 does of similar age were used. Blood samples were collected on a monthly basis for a period of 12 months by jugular venipuncture following an overnight fast. Samples could not be collected from Loskop farm in February and August. Blood was collected into tubes on ice using Na-EDTA as anti-coagulant, and plasma was aspirated within two hours of collection following centrifugation at 3000 x g. Separate aliquots of plasma were stored at -15^{o}C until analysis for urea (Berthelot method, Reagents Applications Inc., San Diego, California), glucose (glucose oxidase method, Reagents Applications Inc., San Diego, California), and cholesterol (cholesterol esterase method, South African Institute for Medical Research, Sandringham, South Africa). Samples taken during the lactation periods were analyzed for total protein (biuret method, Reagents Applications Inc., San Diego, California).

Data was analyzed statistically for differences between months using the Friedman test, and for differences between localities and between physiological states using the T-test procedure (SAS, 1990; BMDP, 1993). For analysis of the effect of location within months, the full data set was used (n=31 for Loskop; n=21 for Delftzyl). For analysis of the effect of month within location, only animals for which a complete data-set was available were used for analysis (n=16 for Loskop; n=15 for Delftzyl). For analysis of the effect of physiological state within location and month, data from 22 lactating and 7 non-lactating animals were used in the case of Loskop, and 12 lactating and 9 non-lactating animals in the case of Delftzyl.

Results and discussion

The climate at both locations is characterized by a cool, dry winter and a hot summer rainfall season (Table 1).

Table 1 Rainfall (mm) and temperatures (degrees Celsius) at the experimental sites

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Delftzyl												
Maximum temperature	31.0	29.3	28.4	26.4	24.1	22.2	22.8	25.8	30.3	31.2	30.2	29.8
Mimimum temperature	18.7	18.8	15.6	12.8	10.1	4.3	4.8	8.5	13.2	17.7	17.6	16.6
Rainfall	185.5	153.8	160.8	25.3	24.0	0.0	0.0	3.1	4.5	63.2	134.2	71.0
Loskop												
Maximum temperature	30.3	28.4	27.8	25.2	23.6	21.9	22.9	25.9	29.8	30.4	30.0	28.8
Mimimum temperature	19.1	18.3	15.8	13.5	11.1	6.6	6.9	9.6	13.8	17.1	17.5	17.0
Rainfall	50.5	309.9	82.9	65.0	39.5	0.0	0.0	0.0	0.0	53.7	88.5	113.6

Under these conditions, nutrient intake would typically decrease from April onwards as temperatures and rainfall decrease, reach a low-point during the winter months (June to September) when plant material is dormant, and then increase as new shoots start appearing on trees and shrubs with the onset of warmer temperatures (September/October) and grass shoots emerge following summer rains (October/November). In general, the patterns of plasma concentrations of glucose, urea and protein (Table 2) were consistent with this, indicating that these blood metabolites are sensitive to seasonal variations in nutrient intake. Although the quantity and quality of available nutrient resources for a particular month would

be expected to be comparable at both locations because of similar precipitation and temperature patterns, the nutrient requirements and hence nutritional status of the animals for any particular month of the year would have differed markedly because of the different mating seasons practised at these two locations. This may have contributed to the many differences (Table 2) observed between locations.

Table 2 Mean blood metabolite concentrations (mg/dl ± s.e.) in indigenous goats at two locations (Loskop *vs*. Delftzyl)

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Urea												
Delftzyl	15.34	15.53	13.64	15.42	18.55	19.8	19.33	17.35	14.47	20.72	20.09	21.22
	± 0.704	± 0.789	± 0.420	± 0.449	± 0.873	± 0.967	± 0.560	± 0.739	± 0.618	± 0.543	± 0.762	± 0.495
Loskop	17.99		16.2	12.93	9.96	17.82	13.94		15.13	17.67	16.113	16.61
	± 0.646		± 0.628	± 0.670	± 0.419	± 0.662	± 0.397		± 1.057	± 0.749	± 0.581	± 0.417
Significance	**		**	**	**	NS	**		NS	**	**	**
Glucose												
Delftzyl	47.33	63.22	58.01	49.07	46.28	63.41	58.17	50.77	61.66	66.7	69.77	63.49
	± 2.070	± 2.031	± 1.877	± 1.940	± 1.828	± 4.957	± 4.316	± 2.275	± 1.360	± 2.119	± 1.811	± 1.861
Loskop	60.53		57.34	60.73	54.22	78.27	69.06		65.73	67.61	58.34	63.71
	± 1.845		± 2.170	± 1.487	± 1.288	± 2.359	± 2.304		± 2.229	± 2.276	± 1.87	± 3.014
Significance	**		NS	**	**	**	*		NS	NS	**	
Protein												
Delftzyl						7.24	7.08	7.49	7.34	8.116	7.65	7.56
						± 0.107	± 0.115	± 0.166	± 0.118	± 0.140	± 0.105	± 0.153
Loskop						7.3	6.89		6.65	7.35	7.91	7.81
						± 0.088	± 0.081		± 0.167	± 0.087	± 0.227	± 0.116
Significance						NS	NS		**	**	NS	NS
Cholesterol												
Delftzyl	80.39	73.81	69.67	69.08	60.26	65.35	53.44	63.47	46.52	38.3	51.28	52.48
	± 2.598	± 3.423	± 2.825	± 2.878	± 2.235	± 2.911	± 3.636	± 2.200	± 2.267	± 3.480	± 1.579	± 2.149
Loskop	70.79		55.76	60.36	58.15	66.5	59.05		57.08	55.47	58.37	43.62
	± 1.838		± 1.916	± 2.229	± 2.967	± 2.600	± 1.660		± 2.495	± 2.238	± 3.286	± 1.585
Significance	**		**	*	NS	NS	NS		**	**	P < 0.06	**

* P < 0.05; ** P < 0.01; NS: P > 0.05

At Delftzyl farm, plasma glucose concentrations decreased from February onwards (Figure 1) and reached their lowest levels just prior to the kidding season (glucose concentrations for May were lower (P < 0.01) than in February and June, September, October, November and December). Decreases in glucose concentrations during pregnancy have been reported in sheep subject to dietary restriction (Oddy & Holst, 1991) and in goats subject to energy restriction (Hussain *et al.*, 1996), suggesting that the plane of nutrition at Delftzyl farm was insufficient to satisfy glucose

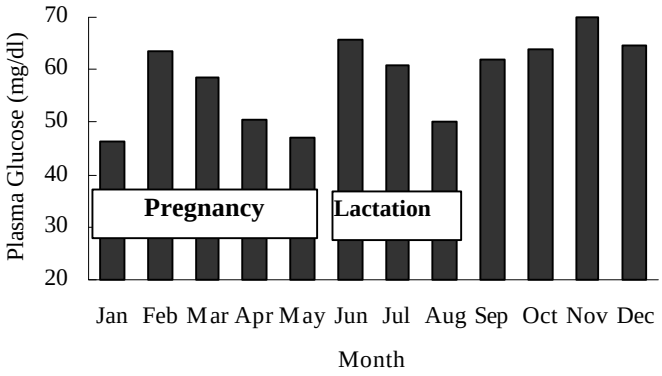

Figure 1 Mean plasma glucose concentrations in Indigenous goats at Delftzyl farm

requirements for pregnancy. The pattern observed is probably due to a combination of increasing glucose utilization by the developing fetus and a simultaneous decrease in the intake of glucose precursors as vegetative growth slowed with the onset

of the dry winter months. Glucose concentrations at Delftzyl farm increased sharply at parturition (Figure 1), and subsequently decreased until the end of lactation (August) when they were lower ($P < 0.01$) than during the following four months (September - December). Although a similar peri-parturient increase in glucose concentrations has been demonstrated in dairy goats (Mbassa & Poulsen, 1991) and dairy cattle (Ward *et al.*, 1995) and is probably associated with increased homeorhetic stimuli in support of gluconeogenesis for lactose synthesis, both authors reported an increase in blood glucose concentrations during lactation. In dairy goats browsing Mediterranean shrubland, however, lower blood glucose concentrations were associated with lower levels of concentrate supplementation, and decreased milk production rates (Landau *et al.*, 1993).

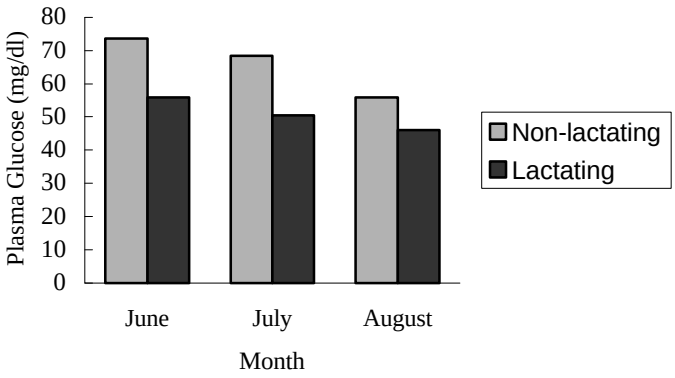

Figure 2 Mean plasma glucose concentrations in lactating and non-lactating indigenous goats at Delftzyl farm

The lower plasma glucose concentrations during the first two months of lactation in lactating *vs*. non-lactating does at Delftzyl farm ($P < 0.05$; Figure 2) suggest that the combination of increased utilization of glucose for milk lactose synthesis and the low intake of nutrients during the winter months was insufficient to maintain blood glucose homeostasis. In contrast, mean monthly plasma glucose concentrations during lactation at Loskop farm, which took place during the summer (October - December), did not differ from those recorded during the four months following weaning ($P > 0.05$). Plasma glucose concentrations of lactating does did not differ ($P > 0.05$) from those of non-lactating does either. Mean plasma glucose concentrations during lactation at Loskop farm were also higher than at Delftzyl farm (month 1 of lactation: 66 *vs.* 56 mg/dl; month 2: 60 *vs.* 51 mg/dl; month 3: 60 *vs*. 46 mg/dl). The different responses during lactation at the two locations can be attributed to the fact that lactation at Loskop farm coincided with peak nutrient availability during the summer period of vegetative growth, whereas lactation at Delftzyl farm coincided with low nutrient availability and quality during the winter period of plant dormancy. The fact that lactating does at Delftzyl farm were unable to maintain glucose homeostasis during pregnancy and lactation suggests that the quantity and quality of nutrients available at this time of year were inappropriate for the kidding season chosen.

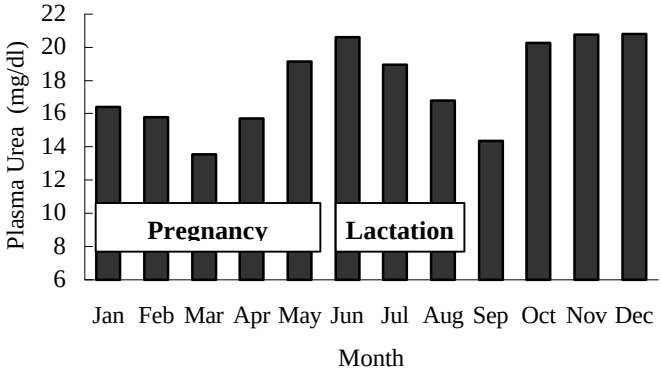

Figure 3 Mean plasma urea concentrations in indigenous goats at Delftzyl farm

At Delftzyl farm, plasma urea concentrations were elevated during the last month of pregnancy and the first two

months of lactation (Figure 3), and were also higher during lactation than those recorded at the summer kidding site (Loskop) (month 1 of lactation: 20 *vs*. 18 mg/dl; month 2: 20 *vs*. 16 mg/dl; month 3: 17 *vs*. 16 mg/dl). Although blood urea concentrations are positively related to crude protein intake when diets containing sufficient energy are fed (Rowlands, 1980), several authors have shown that high urea concentrations can also be induced by low energy diets (Richardson & Kegel, 1980; Wiley *et al*., 1991; Diab & Hillers, 1996). The high urea concentrations during late pregnancy and early lactation in the winter kidding system, together with the low plasma glucose concentrations observed suggest that body protein reserves were catabolized to support glucose synthesis. Plasma urea concentrations at Delftzyl (winter lactation) decreased (Figure 3) towards the end of lactation (urea concentrations during June and July were higher than in September; $P < 0.01$), and were lower in the month after lactation (September) than in the following three months (October, November, December; $P < 0.01$). In contrast, Mbassa & Poulsen (1991) observed that urea concentrations increased during late lactation in dairy goats. In the summer lactation system (Loskop farm), plasma urea concentrations did not differ ($P > 0.05$) during lactation. Plasma protein concentrations, which are held to be a reliable index of long-term body protein status (Rowlands, 1980) and are usually maintained until body protein stores are markedly depleted (Ganong, 1993), were lower during lactation at Delftzyl than at Loskop. This suggests that body protein reserves were depleted during the winter lactation at Delftzyl farm, and may account for the decrease in plasma urea concentrations during lactation at this location.

High plasma cholesterol concentrations in the absence of excess dietary energy intake are considered to reflect the capacity of the animal to mobilize body fat reserves (Ingraham, 1988; Ruegg *et al.*, 1992). Plasma cholesterol concentrations were higher ($P < 0.05$) in lactating goats during months two and three of lactation (July, August) than in non-lactating goats at Delftzyl farm but not at Loskop farm ($P > 0.05$); furthermore, plasma cholesterol concentrations during the winter lactation at Delftzyl farm were also substantially higher than during the summer lactation season at Loskop farm (month 1 of lactation: 68 *vs.* 56 mg/dl; month 2: 60 *vs.* 57 mg/dl; 68 *vs*. 45 mg/dl). This suggests that body adipose tissue reserves were catabolized during the winter lactation at Delftzyl farm to provide energy for extra-mammary tissues, possibly as a result of depleted glucose precursor reserves.

Conclusions

It is concluded that the plasma concentrations of all the blood metabolites studied were sensitive to seasonal changes in nutrient supply, and that they could be of use as indicators of nutritional status in situations in which conventional methods of nutritional assessment are difficult to apply. Plasma glucose concentrations were also sensitive to changes in nutrient demand (i.e. altered physiological state), raising the possibility that they could be employed to evaluate the suitability of genotypes with different milk production potentials within a given nutrient environment. Further research is needed to define critical blood metabolite concentrations, especially with regard to key indices such as milk production and reconception rates.

Acknowledgements

The authors would like to thank the Department of Agriculture (Northern Province) for the use of facilities at Delftzyl Experimental farm, and the Agricultural Research Council and C. Enslin for the use of facilities at Loskop South Experimental farm. This research was supported by a grant from the Foundation for Research Development. Sadly, P. du Toit, who provided valuable assistance at Delftzyl farm, passed away before publication of this research – may he rest in peace.

References

BMDP, 1993. BMDP statistical software inc. 12121 Wilshire Boulevard, suite 300, Los Angeles, CA 90025, USA.

Cronjé, P. B. and Pambu-Gollah, R., 1996. The use of blood profiles as animal response indicators. Bulletin of the Grassland Society of Southern Africa 7 (Supplement 1), 28-35.

Diab, I. A. K. and Hillers, J. K., 1996. Effect of selection for milk yield and dietary energy on yield traits, bovine somatotropin and plasma urea nitrogen in dairy cows. J. Dairy Sci. 79, 682-688.

Ganong, W. F., 1993. Review of medical physiology. Prentice Hall International, London.

Hussain, Q., Harevoll, O., Eik, L.O. and Ropstad, E., 1996. Effects of energy intake on plasma glucose, non-esterified fatty acids and aceto-acetate concentration in pregnant goats. Small. Rumin. Res. 21, 89-96.

Ingraham, R. H. and Kappel, L. C., 1988. Metabolic profile testing. Veterinary clinics of North America: Food Animal Practice 4, 391- 411.

Landau, S. Vecht, J. and Perevolotsky, A., 1993. Effects of two levels of concentrate supplementation on milk production of dairy goats browsing Mediterranean scrubland. Small Rum. Res. 11, 227-237.

Mbassa, G. K. and Poulsen, J. S. D., 1991. Influence of pregnancy, lactation and environment on some clinical chemical

reference values in Danish Landrace dairy goats (Capra hircus) of different parity - II. Plasma urea, creatinine, bilirubin, cholesterol, glucose and total serum proteins. Comp. Biochem. Physiol. 100B, 423-431.

NRC, 1981. Nutrient requirements of domestic animals, no 15: nutrient requirements of goats. National Academy of Sciences, Washington, DC.

Oddy, V. H. and Holst, P. J., 1991. Maternal-foetal adaptation to mid pregnancy feed restriction in single-bearing ewes. Aust. J. Agric. Res. 42, 969-978.

Payne, J. M., 1978. The Compton metabolic profile test. In: The use of blood metabolites in animal production. Ed. Lister, D., Occasional Publication No 1, British Society of Animal Production, Milton Keynes, pp. 3-12.

Richardson, F. D. and Kegel, L., 1980. The use of biochemical parameters to monitor the nutritional status of ruminants. Zim. J. Agric. Res. 18, 53-64.

Rowlands, G. J., 1980. A review of variations in the concentrations of metabolites in the blood of beef and dairy cattle associated with physiology, nutrition and disease, with particular reference to the interpretation of metabolic profiles. Wld. Rev. Nutr. Dietetics 35, 172-235.

Ruegg, P. L., Goodger, W. J., Holmberg, C. A., Weaver, L. D. and Huffman, E. M., 1992. Relation among body condition score, milk production, and serum urea nitrogen and cholesterol concentrations in high-producing Holstein dairy cows in early lactation. Am. J. Vet. Res. 53, 5-9.

Russel, A.,1985. Nutrition of the pregnant ewe. Veterinary Record (In Practice) January 1985, 23-28.

SAS, 1990. SAS procedure users guide version 6, third edition. SAS Instutute inc., USA.

Ward, W. R., Murray, R. D., White, A. R. and Rees, E. M., 1995. The use of blood biochemistry for determining the nutritional status of dairy cows. In: Recent advances in animal nutrition. Eds. Garnsworthy, P.C. & Cole, D. J. A., Nottingham University Press, pp 29-51.

Wiley, J. S., Petersen, M. K., Ansotegui, R. P. and Bellows, R. A., 1991. Production from first calf heifers fed a maintenance or low level of prepartum nutrition and ruminally degradable protein postpartum. J. Anim. Sci. 69, 4279-4293.