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in

Priolo A. (ed.), Biondi L. (ed.), Ben Salem H. (ed.), Morand-Fehr P. (ed.).
Advanced nutrition and feeding strategies to improve sheep and goat

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 74

2007
pages 451-455

Blood metabolites as indicators of energy status in goats

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SUMMARY – With the aim to identify the blood metabolites that are most indicative of the animal's energy status, an experiment was carried out with two groups of six uncastrated male growing goats of the Granadina breed. As well as the intake of metabolisable energy, plasma concentrations of glucose, non-esterified fatty acids, triglycerides and ß-hidroxybutirate were measured. A multivariate factorial analysis was performed to establish the patterns of relationships between the different variables. From the results obtained it was deduced that the plasma concentration of non-esterified fatty acids presented the closest relation with the intake of metabolisable energy, being capable in itself of indicating the animal's energy status.

Keywords: Energy status, blood metabolites, goat species.

RESUME *– "Les métabolites sanguins en tant qu'indicateurs du statut énergétique des caprins". Dans le but d'identifier les métabolites sanguins les plus indicatifs du statut énergétique de l'animal, une expérience avec deux groupes de caprins mâles de race Granadina a été menée. En plus de l'ingestion d'énergie métabolisable, les concentrations plasmatiques de glucose, les acides gras non estérifiés, les triglycérides et β-hydroxybutyrate ont été mesurés. Afin d'établir le modèle de relation existant entre les différentes variables, une analyse factorielle multivariable a été effectuée. Il semble ressortir des résultats obtenus que la concentration plasmatique des acides gras non estérifiés présentait une relation plus étroite avec l'ingestion d'énergie métabolisable, se montrant ainsi capable d'indiquer par elle-même le statut énergétique de l'animal.*

Mots-clés : *Statut énergétique, métabolites sanguins, espèce caprine.*

Introduction

Various purposes may be served by including in the ruminant diet a protected fat that is particularly rich in certain fatty acids (Ashes *et al*., 1992; Franklin *et al.,* 1999; Petit *et al*., 2002; Sanz Sampelayo *et al*., 2002). In such cases, it is interesting to determine whether the effects produced are the result of the particular composition of the fat or, simply, of the different energy status that may derive from the consumption of the supplemented diet (Stapples *et al*., 1998). However, under certain production conditions the dry matter intake cannot be established.

As Russel and Wright (1983) reported, changes in live weight and in body condition reflect nutritional adequacy in the long term, but by the time measurable changes in these parameters have been observed, irreversible production penalties may have been incurred. According to these authors, a more immediate means of assessing the energy status might be reached by the determination of concentrations of certain blood metabolites, particularly those that are closely related to energy metabolism.

In accordance with the above, here are presented results obtained in growing male goats which were fed with a diet nonsupplemented or supplemented with 3% of polyunsaturated fatty acids-rich protected fat. Together with the metabolizable energy intake and with the aim to identify at the blood level the metabolites that are most indicative of the animal's energy status, plasma concentrations of glucose, non-esterified fatty acids (NEFA), triglycerides and ß-hidroxybutirate (BHB) were measured.

Material and methods

Two groups each of six uncastrated male, growing goats of the Granadina breed, age 8 to 12

months, were given a diet comprising a forage fraction, containing lucerne hay (400 g per animal per day) and cereal straw (100 g per animal per day), together with a concentrate fraction (600 g per animal per day). The concentrate fraction was supplemented with 0 or 60 g/kg dry matter (DM) of rumen-protected fish oil. The quantity and composition of the concentrates and forages were sufficient for the animal's nutritional requirements (Aguilera *et al*., 1991). The original fat was a fish oil. The calcium salts of the fish oil fatty acids were obtained by the double-decomposition method described by Jenkins and Palmquist (1984). Specific details of this process were reported by Fernández *et al*. (2004). This product was incorporated into the concentrate replacing an equal weight of maize. The protected fat contained 850 g/kg of DM, with 706 g fat per kg DM. Table 1 shows the composition of the concentrates and of the two types of forage supplied.

Table 1. Composition of concentrate mixtures used (g/kg) their chemical composition and that of lucerne hay and cereal straw (g/kg DM)

	Concentrate[†]		Lucerne hay	Cereal straw
	Standard	Supplement		
Ingredients				
Oats	220	220		
Maize	250	150		
Lupine	490	490		
Protected fat	-	100		
Mineral-vitamin complement	40	40		
Chemical composition				
Dry matter	876	889	875	894
Organic matter	936	949	885	948
Crude protein	213	208	240	47
Fat	46	108	15	-
NDF	431	406	393	741
ADF	117	147	255	458

[†]Concentrates: with 0 (standard) and 6% (supplement) of a protected fat.

The total duration of the experiment was 37 days. The animals were first adapted to the fat-supplemented concentrate, by gradually replacing the standard concentrate by the supplemented one. Following this adaptation period (after about 10 days), the animals were kept under experimental conditions for a further 20 days. The goats were then housed individually in metabolism cages for 7 days and at 09.00 h of each day, refusal of the previous day' food together with the faeces, were recovered and quantified. Subsequently, the animals were given their daily food, with water permanently available *ad libitum*. According to the gross energy intakes and the energy faecal flows, it was possible to calculate the digestible energy intakes (Fernández *et al*., 2004). Finally, intakes of metabolizable energy were estimated as 0.86 of the intake of digestible energy.

One day before beginning of balance trials blood samples were obtained by jugular venepuncture at 09.00 h. The blood was allowed to clot and centrifuged at 1500 g for 10 minutes; the serum was then removed and stored at -30ºC until required for analysis. Serum glucose, NEFA, triglycerides and BHB were determined spectrophotometrically using commercial kits (Randox GL 2623, FA 115, TR 210 and RB 1007).

To determine the patterns of relationships between the different variables, multivariate factorial analyses were performed using the factorial procedure of SAS (1987); the algorithm used was PRO FACTOR. The correlation matrix was selected. The methods for the factor extraction and rotation were principal component analysis and varimax, respectively (SAS, 1987). The number of factors derived depended on the fraction of the total variance that each of the factor explained as well as on the extent to which each variable defined them. The variables considered were the metabolizable energy intake ($kJ/kg^{0.75}$ per day), and the serum levels of glucose (mmol/l), NEFA (mmol/l), triglycerides (mmol/l) and BHB (mmol/l).

Results and discussion

Table 2 gives the mean values of the different measured variables according to the type of the concentrate consumed, and Table 3 shows the results obtained from the multivariate factorial analysis carried out. Three different factors were derived accounting for 33.01% (first factor), 30.86% (second factor) and 20.94% (third factor) of the total variance. In accordance with the factor loadings, the first factor was mainly determined by the serum level of NEFA with positive loading value and by the metabolizable energy intake with negative loading value. The second factor was mainly determined by the serum level of glucose with positive loading value and by the serum level of BHB with negative loading value. Finally, the third factor was mainly determined by the serum level of triglycerides with positive loading value.

Taking into account the available information about the possibility of using levels of certain blood constituents in the determination of energy status in the ruminant, it is postulated that levels of plasma non-esterified fatty acids are the most reliable. Together with this, levels of blood ketones are also considered useful and hypoglycaemia is recognized as an indication of low energy intake (Bowden, 1974; Dunshea and Bell, 1988; Russel and Wright, 1983; Vecht *et al*., 1991; Reist *et al*., 2002).

The results obtained in this experiment agree with the previous findings. The plasma concentrations of NEFA presented the closest relation with the intake of metabolizable energy, being capable in itself of indicating the animal's energy status. Together with this and according to the variables that particularly defined the second factor, the latter showed that the availability of glucose prevents the formation of ketone bodies. Finally, the third factor, being defined only by the plasma concentrations of triglycerides, was shown to be variable, among those considered, that was most independent of the others, a finding that would have to do with the type of provided diets.

Table 2. Metabolizable energy intake (MEI; kJ/kg$^{0.75}$ per day), and the serum levels of glucose (mmol/l), NEFA (mmol/l), triglycerides (mmol/l) and BHB (mmol/l) according to the type of concentrate consumed

	Concentrate[†]	
	Standard	Supplement
MEI	690.3	753.4
Glucose	4.107	3.461
NEFA	0.799	0.642
Triglycerides	0.262	0.237
BHB	0.175	0.226

[†]Concentrates: with 0 (standard) and 6% (supplement) of a protected fat.

Conclusion

According to the obtained results, it is possible to conclude that the plasma concentrations of NEFA is capable in itself of indicating the energy status of the kind of animal considered in this study.

Acknowledgments

This study was supported financially by the Science and Technology Ministry (Spain) (Project: INIA, ZR00-010-C).

Table 3. Factor pattern for the metabolizable energy intake (MEI), and serum levels of glucose, NEFA, triglycerides and BHB[†]

	Factor matrix		
Variable	Factor 1[††]	Factor 2[†††]	Factor 3[††††]
MEI	-0.7964	0.1061	-0.4979
Glucose	0.1591	0.8579	0.0960
NEFA	0.9172	0.0645	-0.2953
Triglycerides	-0.0516	0.1955	0.9459
BHB	0.1668	-08199	-0.0957

	Final statistics	
Factor	Variance explained (%)	Cumulative variance explained (%)
1	33.01	33.01
2	30.88	63.89
3	20.94	84.83

[†]Results were derived from multivariate analysis.
[††]Expressed mainly by the levels of NEFA and MEI.
[†††]Expressed mainly by the levels of glucose and BHB.
[††††]Expressed mainly by the levels of triglycerides.

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