INTERACTIONS BETWEEN NUTRITION, BLOOD METABOLIC PROFILE AND MILK COMPOSITION IN DAIRY GOATS

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Abstract

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The aim of this study was to investigate changes in the concentrations of blood and milk constituents of dairy goats under the effects of stable diet and grazing during lactation from April to June. The experiment was carried out on 10 dairy goats fed a ration composed of concentrate mixture, sugar beet silage and grass hay during winter season (stable diet), and pasture season. Jugular blood and milk samples were taken from all goats during lactation months of April through June at one-month intervals. The blood concentration of total protein (TPP), urea, glucose, triacylglycerols, total ketones, serum non-esterified fattty acids (NEFA), Na, K, Ca, inorganic phosphorus (Pi), Cu, Zn, aspartic amino transferase (AST), γ-glutamyl transferase (GGT), creatine kinase (CK), lactate dehydrogenase (LDH), pH and haemoglobin (Hb) were determined. The measurements of milk contents of fat, protein, casein, urea, lactose, citric acid, total ketones, pH and titratable acidity were performed, too. The results showed variations in serum NEFA, plasma triacylglycerols, Pi , plasma CK and plasma urea during the first months of lactation. In addition to milk levels of total ketones, citric acid, fat and urea were changed. Highest correlation coefficients were found between plasma and milk urea ($r = 0.88$; $p < 0.001$). However, there were correlations between milk fat, plasma urea, blood haemoglobin, plasma glucose, plasma triacylglycerols, blood total ketones and plasma Mg. Citric acid in milk was positively correlated with plasma glucose ($r= 0.46$; $p < 0.01$) and negatively with plasma total protein ($r = - 0.31$; $p < 0.05$). In conclusion, high concentration of serum NEFA, blood total ketones and plasma urea in addition to the decline in the milk concentrations of citric acid and protein, along with increase in milk concentrations of ketone bodies and urea during the first lactation months were observed and may be associated with corresponding energy deficit and induce considerable metabolic changes in dairy goats.

Dairy goats, feeding, blood constituents, milk values, interrelationships

Quantitative and qualitative milk production of dairy goats depend upon nutritional supply (Greppi et al. 1995). An isotonic equilibrium exists between blood and milk, however, such an equilibrium between individual components of blood and milk does not exist. The cells of lactating mammary glands utilize as much as 80 % of available nutrients for synthesis of milk from blood.The primary precursors of milk constituents are free amino acids, glucose, acetate, fatty acids and triacylglycerols from which milk proteins, lactose and milk fat are produced. Limiting any of these will reduce milk production and change its composition (Jelínek et al. 1996). Changes in the blood and milk constituents during lactation in dairy goats under stable diet and grazing conditions were reported by Khaled et al. (1998b).The concentration of urea in blood and milk is affected not only by dietary intake of crude protein digestible in the rumen but also by balance between energy and protein in the diet (Gustaffson et al. 1987; Hoffman and Steinhofel 1990). Increasing the intake of digestible crude protein or digestible crude protein/MJ of metabolizable energy increases the urea content in blood and milk (Grings et al. 1991). Feeding a balanced nutrition to goats was found to reduce the

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concentration of urea in milk. The blood ketone body concentration is reported to be negatively correlated to energy balance (Halse et al. 1983). An increasing ratio between milk acetone and total ketone bodies was observed with increasing total concentration of ketone bodies in blood. The effect of production diseases on milk composition confirmed that there is a close relationship between blood values and milk constituents, reduction in milk proteins during metabolic alkalosis (Illek et al. 1994), reduction in milk fat during rumen acidosis and reduction in lactose in all metabolic disorders (Bergamini 1987).

The aim of this study was to investigate changes in the concentrations of blood and milk constituents of dairy goats under the effect of stable diet and grazing conditions from April to June.

Materials and Methods

Animals and management

The study was carried out on 10 healthy dairy goats. Average individual body weight was 45-50 kg. Lactating goats were machine-milked, and their average daily milk yield was 2-4 kg. The animals were managed under both stable and grazing conditions during the lactation months of April and June.

Feeding and nutrition

Lactating goats were fed a diet formulated to contain 13.64 % CP and composed of 47.0 % (DM-based) concentrate mix (Table 1), 43.0 % grass hay and 10.0 % sugar beet silage and they had free access to lick salts during indoor season. They were gradually accustomed to grazing on grass pasture at the beginning of June. Samples of the concentrate mix, grass hay, sugar beet silage, grass pasture and the diet were analyzed (Table 2) for DM, CP, ether extract, CF and ash, according to A.O.A.C. (1990).

Table 1
Ingredient composition of the diet

Ingredient		Ration
	(% of mix)	(% of DM)
Concentrate mix:		47. 00
Barley	66.00	
Oats	33. 00	
Mineral mix	1. 00	
Grass hay		43. 00
Sugar beet silage		10. 00
Common salt (Salt block)		ad lib.

Table 2
Composition of concentrate mix, grass hay, sugar beet silage, grass pasture and the diet

Measurement	Concentrate mix	Grass hay	Sugar beet silage	Grass pasture	diet[1]
DM %	88.50	81.19	18.22	20.00	62.54
% of DM					
CP %	15.25	11.98	13.53	20.48	13.64
Ether extract %	2.23	2.31	2.56	4.0	2.30
CF %	5.20	34.68	14.59	22.86	18.85
NFE %	74.47	43.56	48.98	44.18	58.67
ASH %	2.85	7.47	20.34	8.48	6.54
M.E Mcal	3.10	2.15	2.24	2.30	4.90

[1]Calculated

Samples and measurements

Jugular blood and milk samples were taken from all goats during lactation months of April and June at one-month intervals. The plasma concentrations of total protein (TPP), urea, glucose, triacylglycerols, AST, GGT, CK, LDH were determined using automated analyzer (Cobas Mira S, Roche) and according to the methods described in the diagnostic kits.The determinations of plasma minerals which included Na, K, Ca, Pi, Cu, Zn, were performed by flame atomic absorption (Hilger H 1550). Concentrations of total ketone bodies using whole blood were measured by the method described by Hradecký et al. (1978) and by using Gas chromatography (Chrom 5 Laboratory instruments Prague). The concentration of blood haemoglobin was determined using Haemoglobinometer (Coulter electronics Ltd. Coldharbour Lane, Harpenden, Herts, UK) and blood pH value was assessed by Astrup method using Acid-base Laboratory (ABL 4 Radiometer, Copenhagen-Denmark). The basic milk constituents including milk fat was determined by the Gerber method according to A.O.A.C. (1990), whereas lactose was measured polarimetrically. The levels of protein and casein were performed by the photometric methods using a Pro-Milk apparatus (Foss Electric, Denmark). The milk contents of urea and citric acid were determined by photometric methods using an automatic analyzer (Cobas Mira S), total ketones in milk were determined as in blood.

Statistical analysis of the data

Means, standard error of the mean (SEM) and coefficient of variance (CV) were calculated. The interrelationships were expressed by linear correlation coefficients as outlined in Statgraphics (STSC Inc. and Statistical Graphics Corp. 1985).

Results and Discussion

The basic statistical characteristics of selected blood variables are presented in Table 3. The results have shown that the highest variability for all evaluated blood constituents and (CV) was found for serum NEFA (98%), followed by 54.17% for plasma triacylglycerols,

Table 3
Principle blood plasma values of dairy goats

Variables		Mean ± SEM	CV
pH		7.39 ± 0.01	0.44
Hb	$g \cdot l^{-1}$	88.2 ± 1.74	12.44
TPP	$g \cdot l^{-1}$	71.19 ± 0.89	7.98
Urea	$mmol \cdot l^{-1}$	8.87 ± 0.37	26.45
Glucose	$mmol \cdot l^{-1}$	3.32 ± 0.07	14.03
AST	$\mu kat \cdot l^{-1}$	1.74 ± 0.04	15.60
GGT	$\mu kat \cdot l^{-1}$	0.85 ± 0.03	21.47
CK	$\mu kat \cdot l^{-1}$	2.09 ± 0.09	27.51
LDH	$\mu kat \cdot l^{-1}$	13.97 ± 0.56	25.36
Triacylglycerols	$mmol \cdot l^{-1}$	0.27 ± 0.02	54.17
Blood total ketones	$mmol \cdot l^{-1}$	1.09 ± 0.04	21.06
Na	$mmol \cdot l^{-1}$	144.9 ± 0.44	21.06
K	$mmol \cdot l^{-1}$	4.13 ± 0.08	11.61
Ca	$mmol \cdot l^{-1}$	2.40 ± 0.04	9.76
Pi	$mmol \cdot l^{-1}$	1.92 ± 0.11	35.90
Zn	$\mu mol \cdot l^{-1}$	10.27 ± 0.29	17.84
Cu	$\mu mol \cdot l^{-1}$	18.31 ± 0.44	15.34
Mg	$mmol \cdot l^{-1}$	0.93 ± 0.02	13.05
Serum NEFA	$mmol \cdot l^{-1}$	0.52 ± 0.08	98.00

further by 35.90% for Pi, 27.51% for CK, and 26.45 % for plasma urea. High amount of serum NEFA, blood total ketones and plasma urea in the first lactation months in dairy goats are associated with corresponding energy deficit and induce considerable metabolic changes in high yielding dairy goats (Greppi et al.1995). Values for the metabolic profiles of blood had great effect on the content of urea in milk. This relationships is shown by significant or highly significant correlation for the majority of blood criteria studied and urea concentration in milk (Jelínek et al. 1996). The basic characteristics of selected milk variables are summarized in Table 4. The highest variability in milk values was found for

Table 4
Principle milk values of dairy goats

Variables		Mean ± SEM	CV
Fat	%	4.32 ± 0.16	23.74
Protein	%	2.62 ± 0.04	8.86
Casein	%	1.88 ± 0.03	11.41
Lactose	%	4.53 ± 0.03	4.56
Urea	mmol·l^{-1}	9.22 ± 0.35	23.68
Citric acid	mmol·l^{-1}	5.12 ± 0.22	27.77
Total ketones	mmol·l^{-1}	5.19 ± 0.30	37.14
pH		6.79 ± 0.02	1.79
Titratable acidity	^{0}SH	5.22 ± 0.16	18.86

total ketones (5.19 ± 0.30 mmol^{-1}; 37.14 %) followed by citric acid (5.12 ± 0.22 mmol^{-1}; 27.77 %), fat (4.32 ± 0.16 %; 23.74 %) and urea (9.22 ± 0.35 mmol^{-1}; 23.68 %). The results have shown that decline in the concentrations of citric acid and milk protein and increase in concentrations of ketone bodies and urea in milk indicated negative energy balance in the first lactation months as reported by Illek et al. (1997). The correlations between some blood and milk constituents are presented in Table 5 and show a significant positive

Table 5
Correlation coefficients between blood and milk values of dairy goats

	Milk constituents								
Blood	Fat	Protein	Casein	Urea	Lactose	Citric A	T.Acidity	T.Ketones	pH
pH	-0.04	0.08	-0.09	-0.10	0.21	-0.1	-0.03	-0.12	-0.01
Hb	-.45^{c}	-0.27	-.41^{c}	-0.50^{c}	0.13	-0.24	0.28	-0.57^{c}	-0.40
TPP	-0.15	0.17	0.28	-0.07	0.21	-0.31^{a}	0.04	-0.34^{a}	-0.12
Urea	0.59^{c}	0.22	0.21	0.88^{c}	-0.33^{a}	0.20	-0.01	0.56c	0.37
Glucose	0.36^{a}	-0.08	-0.24	0.21	-0.23	0.40^{b}	0.26	0.29	0.06
Triacyl.	-0.31^{a}	-0.174	-0.07	-0.07	-0.14	-0.09	-0.12	-0.12	-0.12
SNEFA	-0.36^{a}	-0.004	-0.15	-0.17	-0.06	-0.18	0.31^{a}	-0.41^{b}	-0.43^{b}
Total ketones	0.31^{a}	0.45^{c}	0.40^{b}	0.34^{a}	-0.13	-0.12	-0.08	0.21	0.30
AST	0.21	-0.01	-0.04	0.09	-0.33	-0.02	0.36	-0.13	-0.36
CK	0.03	-0.21	-0.18	-0.07	-0.10	0.09	-0.21	-0.08	0.01
GGT	0.03	0.05	-0.18	-0.22	0.25	-0.09	0.21	-0.30	-0.21
LDH	-0.04	-0.25	-0.33^{a}	-0.24	0.01	-0.32^{a}	0.35^{a}	-0.45^{c}	0.44^{c}
Na	-0.1	0.01	0.01	0.01	-0.03	-0.02	0.19	-0.03	-0.16
K	0.03	-0.01	0.08	0.09	-0.09	0.16	-0.001	0.27	0.09
Ca	0.30	0.07	-0.11	0.14	0.12	0.35^{c}	0.22	0.30^{a}	0.18
P	0.09	0.03	0.10	0.18	-0.25	0.11	0.05	0.15	-0.01
Zn	0.19	0.35^{a}	0.22	0.34^{a}	-0.21	-0.15	0.25	0.15	0.10
Cu	0.004	-0.07	-0.22	0.15	-0.05	-0.13	0.25	-0.14	-0.03
Mg	0.32^{a}	0.06	-0.23	0.06	0.06	0.31^{a}	0.26	-0.1	-0.06

a: $p < 0.05$, b: $p < 0.01$, c: $p < 0.00$

correlation (r = 0.88c) between urea content in blood plasma and in milk. A virtually linear dependence has also been found for goat milk (Khaled et al. 1998a), cow milk (Oltner

1983) and ewe milk (Jelínek et al. 1996) as have increased levels of urea in milk during all metabolic disorders of dairy cows (Bergamini 1987). The urea content in milk reflected the uptake of nitrogenous substances. The second milk constituent that is highly affected by blood composition is fat. The highest correlations were found between milk fat content of milk and levels of plasma urea (r = 0.59c), Hb (r = -0.45c), glucose (r = 0.36a), triacylglycerols (r = -0.31 a), total ketones (r = 0.31 a) and Mg (r = 0.32 a). Citric acid contents in milk is highly positive correlated with glucose (r = 0.40 b).and negatively correlated with total protein (r = 0.31 a). Despite the fact that the health of the mammary gland has a great effect on the concentration of lactose, significant relationships were observed between some blood constituents and content of lactose in milk. The highest values of correlation coefficients in relation to the content of lactose were found for concentration of urea (- 0.33a) and AST (- 0.33b).

In conclusion, there were significant variations in blood and milk constituents under the effect of a stable diet and transfer to grazing during the first months of lactation in dairy goats. The correlations between some blood and milk values of milking goats were significant. Nutrition offers a means of making rapid changes in milk composition, but the relationship between feed constituents and milk composition is complex. The level of metabolic processes as demonstrated using selected blood indicators affect the composition of goat milk.

Vztah mezi výživou, metabolickým profilem krve a tvorbou mléka u mléčných koz

Cílem práce bylo zhodnocení změn koncentrace krve a mléčných komponentů u mléčných koz při zkrmování stájové diety a současné pastvy v laktačním období od dubna do června. Do pokusu bylo zahrnuto 10 mléčných koz, jimž bylo nejprve podáváno pouze koncentrované krmivo, siláž z cukrové řepy a seno (stájová dieta), později byli tito jedinci postupně převedeni na pastvu. Od pokusných koz byla odebírána krev z v. jugularis a vzorky mléka v dubnu a v červnu ve třech časových obdobích. V pokusu jsme sledovali koncentraci celkového proteinu (TPP), močovinu, glukózu, triacylglycerol, celkový obsah ketonů, neesterifikované mastné kyseliny (NEFA), sodík, draslík, vápník, anorganický fosfor (Pi), měď, zinek, aspartátaminotransferázu (AST), γ-glutamyl transferázu (GGT), kreatinkinázu (CK), laktát dehydrogenázu (LDH), pH a hemoglobin (Hb). Současně byl sledován obsah tuku, proteinu, kaseinu, močoviny, laktózy, kyseliny citrónové, celkový obsah ketonů, pH a titrační acidita.

Během první laktační periody jsme zaznamenali významné změny u sérových NEFA, triacylglycerolu, Pi, CK a močoviny. Vyšší korelační koeficient byl zjištěn mezi plazmatickou a mléčnou močovinou ($r = 0{,}88$; $p < 0{,}001$); mléčný tuk, plazmatická močovina, krevní hemoglobin, plazmatická glukóza, triacylglyceroly a hořčík byly v korelaci. Kyselina citrónová v mléce pozitivně korelovala s plazmatickou glukózou ($r = - 0{,}31$; $p < 0{,}05$).

U sledovaných jedinců jsme naměřili během prvních měsíců laktace vysokou koncentraci SNEFA, ketonů a močoviny v plazmě, pokles kyseliny citrónové a proteinů v mléce, zvýšený obsah ketonů v mléce a močoviny. Zjištěné hodnoty během laktace jsou vyvolány deficitem energie. Nedostatek energie může být příčinou značných metabolických změn.

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