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Lactation performance and mammary amino acid metabolism in lactating dairy goats when complete or met lacking amino acid mixtures were infused into the jugular vein

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ABSTRACT

To investigate the compensatory responses of mammary gland tissues to deficiency amino acid (AA) supply, two AA mixtures were infused into the jugular vein of lactating dairy goats. Complete AA mixture (mixture 1, +M) contained all the constituents of casein and mixture 1 minus methionine (Met) was used as the deficiency AA supply treatment (−M). The results indicated that deficiency AA infusion decreased milk yield ($P < 0.01$), milk protein content ($P < 0.05$) and yield ($P < 0.01$), but increased mammary plasma flow ($P < 0.01$). Deficiency of Met decreased its arterial concentration ($P < 0.05$) while increased concentration of isoleucine (Ile), leucine (Leu), valine (Val), and phenylalanine (Phe) ($P < 0.05$) or had no significant effect on concentration of lysine (Lys), histidine (His), and argnine (Arg) ($P > 0.05$). The uptake Met by the mammary gland from arterial plasma were increased ($P < 0.05$), and those of other EAA were not changed ($P > 0.05$), except that uptake ratio of Ile was significantly lowered ($P < 0.05$) when −M was infused. Results from this study showed that the capacity of Met absorption by mammary gland could be elevated under the Met shortage condition.

1. Introduction

A large amount of experimental data consistently shows that synthesis of milk protein depends on adequately balanced amino acid supply (Choung and Chamberlain, 1993; Doepel and Lapierre, 2010; Galindo et al., 2011). Different rumen undegradable proteins with different AA profile affect postruminal AA supply and milk protein production (Cyriac et al., 2008; Mabjeesh et al., 1999; Korhonen et al., 2002). For cows fed corn silage and alfalfa-based commercial diets, Lys and Met are thought to be the first and second limiting AA (Rulquin et al., 2006; Schwab et al., 1976). Dietary supplementation of these AA improved milk protein synthesis (Cho et al., 2007). For cows fed grass silage-cereal based diets, His was suggested to be the first limiting AA (Kim et al., 1999; Korhonen et al., 2000; Vanhatalo et al., 1999).

Efficiency of utilization of infused amino acids for milk protein synthesis was not significantly altered in response to increased postruminal lysine and Met flow, but a numerically increased efficiency of utilization of total amino acids was observed (Misciattelli et al., 2003). Dairy goats receiving abomasal infusions of Lys or Lys deleted AA mixture, milk yield decreased by 30% (Ying et al., 2013). On the other hand, mammary gland may regulate AA uptake according to requirements (Korhonen et al., 2002). The animal itself may also have self-regulatory mechanisms to meet

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Table 1
Composition of pelleted diet fed to goats.[d]

Ingredients	Composition (g/kg DM)	Nutrients	Level
Corn	328	DM (%)	88.39
Soybean meal	52	ME (MJ/kg DM)[b]	10.9
Wheat bran	100	MP (g/kg DM)[c]	50.37
Peanut straw	200	Calcium (%)	0.61
Corn stalk	300	Phosphate (%)	0.29
Dicalcium phosphate	5	ADF%	25.37
Salt	5	NDF%	39.41
Premix[a]	10		

[a] Contains (per kg of mix) 1000 KIU vitamin A, 250 KIU vitamin D_3, 2400 mg vitamin E, 2000 mg niacin, 2000 mg Fe, 3000 mg Mn, 3000 mg Cu, 14,000 mg Zn, 100 mg Se, 180 mg I, 40 mg Co.
[b] Calculated by multiplying DE content of the diet (12.98 MJ/kg DM) with 0.84.
[c] Calculated from the RDP, UDP, and FME contents of each ingredient measured in our laboratory according to AFRC 1993 assuming a rumen outflow rate of 0.05 h^{-1}.
[d] Daily allowance of the pelleted diet fed to each goat was 1.3 kg, which contained 12.52 MJ metabolizable energy (ME) and 57.88 g metabolizable protein (MP). For a 35 kg LW dairy goat producing 1 kg milk per day, the ME and MP requirements are 12.3 MJ and 75 g MP, respectively. The pelleted diet fed could meet 101.7% of the energy requirement and 77% of the protein requirement.

the maximum nutrient needs for lactation (Bequette and Backwell, 1997a,b; Korhonen et al., 2000; Mackle et al., 2000), Different substrate in feed supplying with ruminants can modulate mammary blood flow (Davis and Collier, 1985) and changing amino acid uptake rate (Bequette and Backwell, 1997a,b) were considered to be the main mechanisms. The rate of mammary blood flow declined in response to infusions of Met (Guinard and Rulquin, 1995), when Met was not infused, mammary plasma flow was increased as observed with His restriction (Bequette and Hanigan, 2000). But there was no significant results about increasing mammary blood flow under the condition that amino acid deficiency by abomasal infusion (Ying et al., 2013).

The objective was to validate the hypothesis that mammary glands tissues control nutrient supply by regulating blood flow and uptake of specific amino acid species in dairy goats.

2. Materials and methods

2.1. Animals, experimental design, diet and feeding management

Four healthy multiparous lactating Laoshan dairy goats with 35 ± 5 kg of BW and 112 ± 24 day in milk (DIM) in the second parity were used in a cross over experiment. The animals were randomly allocated into two groups at the start of the first period of the experiment (experiment period is two weeks) and assigned to two treatments of infusing AA mixtures containing methionine (+M) or not (−M) via jugular vein. The +M AA mixture was formulated according to the AA composition of casein and the −M AA mixture was the same but without methionine (Table 1). The two treatments were switched over between the two groups of goat in the second period of the experiment.

All goats were fed a same pelleted diet containing 10.9 MJ ME/kg dry matter (DM) and 50.37 g M metabolizable protein (MP)/kg DM. The MP content of the diet was calculated from the rumen degradable protein, rumen undegradable protein and fermentable ME contents of each ingredient measured in our laboratory. Daily feed allowance (1.3 kg/goat) was calculated to meet the recommended requirements of energy and 77% of MP for a goat of 35-kg BW that produces 1 kg/d of milk (Table 2). The diet

Table 2
The composition of L-AA mixtures.

Amino acids	Composition of L-AA mixture (μmmol/d)	
	+M	−M
Lys	30.99	30.99
Met	9.32	0
Thr	23.76	23.76
His	10.95	10.95
Arg	9.76	9.76
Leu	42.84	42.84
Ile	20.89	20.89
Val	36.45	36.45
Phe[a]	33.72	33.72
Ser	28.93	28.93
Glu	87.88	87.88
Gly	10.52	10.52
Asp	29.45	29.45
Ala	15.93	15.93
Pro	73.50	73.50
Total	464.89	455.57

[a] A daily amount of 14.18 μmmol Tyr was substituted by Phe due to the low solubility of Tyr.

was formulated and pelleted at the beginning of the experiment and was used for the entire experiment.

Goats were fed individually in indoor metabolic cages .The animals were allocated to the metabolism cages seven days prior to the start of the experimentation for adaptation and were exercised in individual pen floor 4 h every week. The animals were fed from over-head automatic feeders that distributed daily feed allowance hourly within 24-h cycle and had free access to water during the entire period of experiment. The goats were milked twice daily (0800 and 1830 h).

2.2. Experimental procedure, infusion and sampling

2.2.1. Catheterization of animal

One month before the start of the experiment, the left side carotid artery was elevated to a subcutaneous position according to the method of Bequette and Backwell (1996) and temporary catheters (Silicon, 0.76 mm i.d., 1.65 mm o.d., Jinan Medical Silicon Product Co., No. 8, Second Ring Road, Jinan) were inserted into the elevated carotid artery. Temporary catheters were also inserted into right side jugular vein, which was used for AA infusion. Two catheters were inserted into mammary vein (superficial epigastric vein) one day prior to the arteriovenous difference measurement. One was inserted toward the mammary with the tip being guided by palpation and placed as close as possible to the mammary gland (2–3 cm). This catheter was used for infusion of ρ-amino hippuric acid (PAH). The other was inserted about 10 cm into the vein toward the head, which was used for blood sampling.

2.2.2. Preparation of AA mixture and infusion

The AA mixtures were made up based on the composition listed in Table 1 by dissolving respective L-amino acid (Shanghai Bo'ao Biological Technology Co., Ltd., China) in 1.0 L of 0.9% saline solution. The solution was then filtered through a 0.22 μm adjusted to pH 7.4, and finally autoclaved (120 °C) for 30 min. Solutions were freshly made each day and were continuously infused into the right jugular vein by peristaltic pumps (Model HL-2, Shanghai Huxi Analytical Instrument Co. Ltd., China) during each experimental period. The compression pump was adjusted to the speed to ensure 60 g of AA mixture was infused into each goat within 24 h.

2.2.3. Sampling and measurements

There were seven days in each period of the experiment with the infusion of AA mixture starting on day 1 in each period and continued for seven days. Milk yields were recorded daily and milk samples were taken daily for the last three days. On the last day of each period, mammary blood flow was determined by downstream dye dilution method as described by Katz and Bergman (1969) and Huntington (1989). Blood samples were collected from carotid artery and mammary vein every 2 h for 24 h after

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