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Amino acid utilization of lactating dairy cows when diets are changed from an alfalfa-based diet to cereal straw-based diets

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ABSTRACT

This experiment assessed the utilization of amino acids (AA) by the mammary gland of cows when diets are changed from an alfalfa hay-based diet (AH) to cereal straw-based diets using corn stover (CS) or rice straw (RS). Thirty multiparous Holstein dairy cows were selected and randomly assigned to 1 of 3 treatments (n = 10). After 13 weeks' feeding, arterial and venous plasma were collected every 6 h over 2 days and AA concentrations measured. The cows fed the CS or RS diet had lower milk and protein yield despite similar dry matter intake. The digestive AA flow was predicted to be lower in the cows fed CS or RS than in AH-fed cows. The arterial concentration of methionine and valine was lower in the cows fed RS than in cows fed AH. The mammary uptake of most essential AA, especially branched-chain AA, methionine, and arginine, was greater in the AH-fed cows than in cows fed CS or RS. The ratio of mammary uptake to milk output of methionine was lower in the RS-fed cows than that in the cows fed AH, with a value below 1 for both. In summary, the insufficient supply of free AA from arterial plasma presented to the mammary gland and lower mammary plasma flow restrict the mammary AA uptake for milk protein synthesis when energy is limited. On the other hand, the utilization of leucine and methionine may be a limiting factor for milk protein synthesis and lactation performance when corn stover or rice straw is fed to dairy cows.

1. Introduction

Cereal straws such as corn stover and rice straw are widely available, but their use is limited because of reduced milk production when these forages are fed to dairy cows (Pang et al., 2008; Sarnklong et al., 2010). In our previous study (Wang et al., 2014), cows fed cereal straw-based diets had lower milk yield, lower milk protein yield and lower gross utilization

Abbreviations: AA, mino acids; AD, facid detergent fiber; AH, total mixed ration containing alfalfa hay as the main forage; AV, arterio-venous; BCAA, branched-chain amino acids; CS, total mixed ration containing corn stover as the main forage; CP, crude protein; DM, dry matter; EAA, essential amino acids; MD, the ratio of milk AA output to estimated digestive AA flow; MG, mammary gland; MP, metabolizable protein; MPF, mammary plasma flow; N, nitrogen; NDF, neutral detergent fiber; NEAA, non-essential amino acids; RS, total mixed ration containing rice straw as the main forage; UOAA, uptake to output ratios across the mammary gland.

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Table 1
Ingredients and nutrient composition (mean ± SD) of the total mixed ration containing alfalfa hay (AH), corn stover (CS), or rice straw (RS) as the main forage (n = 3).

	Treatment		
Items	AH	CS	RS
Dietary ingredient, g/kg of DM			
Ground corn grain	270	270	270
Wheat bran	51.0	51.0	51.0
Soybean meal	127	127	127
Cottonseed meal	43.0	43.0	43.0
Beet pulp	10.0	0.0	0.0
Corn silage	150	150	150
Alfalfa hay	230	0.0	0.0
Chinese wild grass hay	70.0	0.0	0.0
Corn stover	0.0	300	0.0
Rice straw	0.0	0.0	300
Urea	0.0	10.0	10.0
Premix[a]	49.0	49.0	49.0
Nutrient composition[b], g/kg of DM			
Organic matter	923 ± 29.6	923 ± 20.6	901 ± 19.9
Crude protein	168 ± 1.51	163 ± 3.98	162 ± 5.81
Neutral detergent fiber	318 ± 14.3	367 ± 10.8	365 ± 12.8
Acid detergent fiber	175 ± 1.50	209 ± 1.45	202 ± 1.49
Non-fiber carbohydrate	408 ± 40.0	353 ± 22.6	348 ± 44.6
Ca	8.10 ± 0.63	6.21 ± 0.71	5.60 ± 0.67
P	4.63 ± 0.18	4.72 ± 0.14	3.89 ± 0.40
NE_L, MJ/kg	6.57	6.07	5.98

[a] Formulated to provide (per kilogram of DM): 174 g of zeolite powder, 1.25 g of yeast, 25 g of mold adsorbent (Solis Mos, Novus International Inc., St. Charles, MO), 21.44 g of KCl, 41.25 g of MgO, 150 g of Salt, 187.5 g of $NaHCO_3$, 84 g of Ca, 15 g of P, 125,000 IU of vitamin A, 750,000 IU of vitamin D3, 937.5 IU of vitamin E, 1750 mg of Zn, 17.5 mg of Se, 28.75 mg of I, 375 mg of Fe, 15 mg of Co, 556.5 mg of Mn and 343.75 mg of Cu.

[b] Non-fiber carbohydrate = 100–% Neutral detergent fiber − % crude protein − % ether extract − % ash; NE_L = Net energy for lactating, calculated based on the Ministry of Agriculture of P. R. China recommendations (MoA, 2004).

efficiency of dietary nitrogen (N) than did those fed alfalfa hay, mainly due to reduced supply of metabolizable protein (MP) and net energy of lactation in a corn stover or rice straw-based diet compared to an alfalfa hay-based diet. Lower milk protein synthesis in the cows fed cereal straws in place of alfalfa hay (Wang et al., 2014) could be attributed to the lower energy consumption and lower microbial synthesis as well as the ingestion of dietary amino acids (AA).

Improved efficiency of N utilization may be achieved by improving the efficiency of AA utilization and by manipulating dairy diets to optimize mammary gland (MG) uptake of essential AA (EAA; Arriola Apelo et al., 2014). An improved representation of the biology of milk protein synthesis should include individual EAA rather than MP and the effects of multiple nutrients on AA utilization (Arriola Apelo et al., 2014). In our previous study (Wang et al., 2014), it was not clear how AA were metabolized and utilized by dairy cows when alfalfa hay was replaced with cereal straws. Therefore, it was necessary to understand AA metabolism in the MG under these diverse nutritional conditions.

The objectives of this study were to investigate the effects of replacing an alfalfa/Chinese wild rye hay mixture with corn stover or rice straw made isonitrogenous by the addition of urea on AA uptake by the MG of dairy cows in mid-lactation, and to identify the potential limiting factors for milk production from AA aspect under these dietary conditions.

2. Materials and methods

2.1. Animals and experimental design

The experimental procedures were approved by the Animal Care Committee at Zhejiang University (Hangzhou, China) and were in accordance with the university's guidelines for animal research.

Feeding and management of the experimental cows have been described previously (Wang et al., 2014). Thirty multiparous Holstein dairy cows (body weight = 600 ± 52.0 kg, milk yield = 30.0 ± 3.53 kg/d, day in milk = 160 ± 27.8 d, parity = 3.4 ± 1.57; mean ± SD) were blocked into 10 groups according to day in milk and milk yield, and were allocated to 3 treatments randomly within groups. Three isonitrogenous treatment diets contained a similar concentrate mixture (550 g/kg) and 150 g/kg corn silage, with 300 g/kg of the diet being treatment forages [dry matter (DM) basis, Table 1]: (1) 230 g/kg alfalfa hay and 70 g/kg Chinese wild rye hay (AH); (2) 300 g/kg corn stover (CS); and (3) 300 g/kg rice straw (RS). Diets were made isonitrogenous by the addition of 10 g/kg urea to the cereal straw-based diets. The chemical composition of individual forage has been described previously (Wang et al., 2014). Cows were fed and milked 3 times daily at 06.30, 14.00, and 20.00 h. After 13 weeks on treatment as part of the larger study, lactation performance was monitored and samples of feeds, milk, and arterial and venous plasma were collected.