EFFECTS OF DIFFERENT STARCH SOURCES ON ENDOGENOUS NITROGEN AND ENERGY LOSSES IN MEAT AND WOOL RABBITS

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ABSTRACT

The effects of different starch sources on endogenous nitrogen and energy losses in meat and wool rabbits were studied comparing the inclusion of corn starch, potato starch and tapioca starch in nitrogen-free diets. Both a total of eighteen 18-months-old healthy meat and wool rabbits weighting 3.00±0.035 kg, on average, were randomly divided into 3 groups, 6 in each group. Diets with different starch sources (potato, corn and tapioca) were fed *ad libitum*. The trial period was 7 days. The results showed that: 1) The dry matter intake of the potato group was higher than the corn group (P<0.05); there was no difference in dry matter intake between corn group and tapioca group (P>0.05), both meat and wool rabbits. 2) The metabolic fecal nitrogen (MFN) of tapioca group was higher than in potato starch group (P<0.05), and the difference of endogenous urinary nitrogen (EUN) in each group was not significant (P>0.05), both in meat and wool rabbits. 3) There were no differences in metabolic fecal energy (FmE) and endogenous urinary energy (UeE) among the three groups (P>0.05), both meat and wool rabbits. In conclusion, the endogenous nitrogen and energy losses in the potato group was the lowest for meat rabbits and wool rabbits.

Key words: Meat rabbits, Wool rabbits, Starch source, Endogenous energy losses, Endogenous nitrogen losses

INTRODUCTION

Endogenous nitrogen and energy losses in the animal reduce the apparent digestibility of protein, the energy utilization of feed, and increase the excretion of animal manure nitrogen, which cause serious economic losses and environmental pollution. The nitrogen-free diet method is the most commonly used method to determine endogenous losses, and has higher accuracy in determining endogenous losses in animals (Li et al., 2019). In this experiment, meat and wool rabbits were used as test animals, and corn starch, potato starch, and tapioca starch were used as starch sources to prepare three different types of nitrogen-free diets. The aim of this work was to study the endogenous nitrogen and energy losses of different starch sources in meat and wool rabbits.

MATERIALS AND METHODS

Animals and experimental design

A total of 18 meat rabbits and 18 wool rabbits, 18-months-old with an average body weight of 3.00±0.035 kg, were randomly divided into 3 groups, 6 in each group, and fed with 3 diets differing in the type of starch, respectively. Rabbits were fed *ad libitum* during 7 days. Feces and urine were collected every morning and health status were observed every day.
The diet was formulated according to the nutritional requirements of the NRC (1995) and Nutritional Content of full price rabbit feed (Gu, 1999). The nitrogen-free diet formula and nutritional levels are shown in Table 1.

Table 1: Ingredients and chemical composition of nitrogen-free diet formula (% DM)

Raw material	Corn starch group	Potato starch group	Tapioca starch group
Arbocel	35.0	35.0	35.0
Opticell	28.1	28.1	28.1
Palm oil	10.0	10.0	10.0
Sucrose	5.00	5.00	5.00
Corn starch	18.0		
Potato starch		18.0	
Tapioca starch			18.0
Limestone	0.71	0.71	0.71
$CaHPO_4 \cdot 2H_2O$	2.37	2.37	2.37
NaCl	0.50	0.50	0.50
Rabbit premix[1]	0.30	0.30	0.30
Chemical composition			
DE (MJ/kg)[2]	10.3	10.3	10.3
Neutral Detergent Fiber	63.1	63.6	64.0
Cellulose	24.8	24.4	24.7
Hemicellulose	26.6	26.9	26.3
Acid Detergent Lignin	11.6	11.2	11.4
Ether Extract	10.0	10.5	10.3
Ca	0.78	0.73	0.80
P	0.56	0.59	0.55

1）The premix provided per kg of the diet: Fe 70 mg，Cu 20 mg，Zn 70 mg，Mn 10 mg，Se 0.25 mg，Co 0.15 mg，I 0.2 mg，VA 10 000 IU，VD 900 IU，VE 50 mg，VK 2 mg，VB_1 2 mg，VB_2 6 mg，VB_5 50 mg，VB_6 2 mg，VB_{12} 0.02 mg，VB_3 50 mg，Choline 1 000 mg，VH 0.2 mg

2）DE (Digestible Energy) was a calculated value, while the others were measured values. DE = GE (Gross Energy) – FE (Energy in Feces)

Chemical Analyses

Procedures of the Association of Official Analytical Chemists International (2000) were used to determine DM, N, EE, Ca, and P of feedstuffs content. Neutral-detergent fibre (NDF), Acid-detergent fibre (ADF), and acid detergent lignin (ADL) were determined sequentially using the filter-bag system (Ankom Technology, New York, NY, USA) according to the method of Van Soest et al. (1991).

Cellulose (%) = ADF (%) – ADL (%);

Hemicellulose (%) = NDF (%) - ADF (%)

Calculation

Basal nitrogen metabolism = endogenous urinary nitrogen (EUN) + metabolic fecal nitrogen (MFN) + Surface losses of nitrogen (SLN), rabbits have a small SLN and are negligible.

Endogenous energy losses = metabolic fecal energy (FmE) + endogenous urinary energy (UeE).

Statistical analysis

All experimental data were statistically analyzed by one-way analysis of variance (ANOVA) using Statistical Packages for the Social Sciences (SPSS) 21.0. The results were expressed as Mean ± Standard Deviation (SD). $P < 0.05$ indicates a significant difference.

RESULTS

There were no significant ($P>0.05$) differences in the body and metabolic weight of the three groups of meat rabbits (Table 2). Comparing dry matter intake and daily fecal output of each group, the potato group was significantly higher than the corn group ($P<0.05$). There was no significant difference in daily urine output among the three groups ($P>0.05$). There were also no significant differences in dry matter intake and daily excrement volume of wool rabbits ($P>0.05$).

Table 2: Effect of different starch sources on body weight, dry matter intake, and daily manure and urinary excretion, in meat and wool rabbits

Item	Animals (n=6)	Corn starch group	Potato starch group	Tapioca starch group
Body Weight (kg)	Meat rabbits	3.23±0.01	3.16±0.09	3.21±0.47
	Wool rabbits	3.48±0.09	3.38±0.05	3.50±0.10
Body Weight$^{0.75}$ (kg)	Meat rabbits	2.41±0.00	2.37±0.05	2.40±0.28
	Wool rabbits	2.55±0.05	2.49±0.03	2.56±0.06
Dry Matter Intake (g/d)	Meat rabbits	70.5±3.52b	87.3±6.08a	80.3±4.67ab
	Wool rabbits	79.3±6.10	89.3±3.25	83.2±4.60
Daily manure excretion (g/d）	Meat rabbits	23.3±3.27b	33.6±2.31a	31.9±2.63ab
	Wool rabbits	27.1±1.57	32.0±4.24	30.5±3.54
Daily urinary excretion（ml/d）	Meat rabbits	155±11.3	149±15.7	142±9.66
	Wool rabbits	173±12.0	158±14.8	178±11.8

In the same row, values with different letter superscripts mean significant difference (P＜0.05)

The fecal nitrogen content of the potato starch group of meat rabbits was significantly lower than the other two groups (P<0.05; Table 3). The MFN of the meat and wool rabbits was significantly different among the groups (P<0.05). Both were highest in the tapioca starch group.

Table 3: Effect of different starch sources on the endogenous nitrogen losses in meat and wool rabbits

Item	Animals (n=6)	Corn starch group	Potato starch group	Tapioca starch group
Fecal nitrogen content (mgN/g)	Meat rabbits	4.70±0.28^{a}	3.25±0.07^{b}	4.60±0.35^{a}
	Wool rabbits	4.75±0.35	4.19±0.10	5.50±0.71
Urine nitrogen content (mgN/ml)	Meat rabbits	4.82±0.31	4.85±0.07	5.50±0.71
	Wool rabbits	4.78±0.68	5.04±0.34	4.74±0.20
Metabolic fecal nitrogen (g/kg DMI)	Meat rabbits	1.55±0.21^{ab}	1.23±0.09^{b}	1.83±0.18^{a}
	Wool rabbits	1.62±0.17^{b}	1.58±0.14^{b}	2.02±0.03^{a}
Endogenous urinary nitrogen (mg/d·BW$^{0.75}$)	Meat rabbits	310±11.4	306±13.7	325±14.2
	Wool rabbits	325±7.40	320±10.7	330±9.11

In the same row, values with different letter superscripts mean significant difference (P＜0.05)

The effects of different starch sources on fecal energy content and urine energy content of meat and wool rabbits were not significant (P>0.05; Table 4). There were also no significant differences in the metabolic fecal energy and endogenous urinary energy among the groups (P>0.05).

Table 4: Effects of different starch sources on the energy losses of meat and wool rabbits

Item	Animals (n=6)	Corn starch group	Potato starch group	Tapioca starch group
Fecal energy content (MJ/kg）	Meat rabbits	16.2±0.98	14.0±0.77	15.8±0.45
	Wool rabbits	18.1±0.86	15.6±0.42	17.9±1.21
Urinary energy content (MJ/L)	Meat rabbits	0.039±0.001	0.036±0.003	0.045±0.007
	Wool rabbits	0.041±0.004	0.044±0.006	0.043±0.003
Metabolic fecal energy (MJ/d·BW$^{0.75}$)	Meat rabbits	0.17±0.02	0.18±0.05	0.21±0.01
	Wool rabbits	0.21±0.03	0.20±0.08	0.23±0.10
Endogenous urinary energy (MJ/ d·BW$^{0.75}$)	Meat rabbits	0.0025±0.0003	0.0022±0.0005	0.0027±0.0007
	Wool rabbits	0.0028±0.0008	0.0028±0.0009	0.0030±0.0004

In the same row, values with different letter superscripts mean significant difference (P＜0.05)

DISCUSSION

Starch is the main component of cereal feed and the most important source of energy for animals. It is mainly composed of amylose (α-1,4-glucosidic linkage) and amylopectin (α-1,6-glucosidic linkage) (Englyst et al., 1992). When amylose/amylopectin ratio is greater than 1, it is considered high amylose content (Zhang et al., 2017). In this experiment, the ratio of amylose/amylopectin in tapioca starch is 0.11 (Liu, 2015), in potato starch is 0.39 (Cai et al., 2019), and in corn starch is 0.23 (Liu, 2015). All of them are low in amylose/amylopectin ratio, but potato starch has the highest amylose content. The dry matter intake of the potato starch group was higher than that of the corn starch group, which was similar to the tapioca starch group. This result may be due to the higher DM intake, higher amylose/amylose ratio and lower dietary energy supply in the potato starch group. This may have a great influence on the digestion of feed protein and cecal starch fermentation, because the fermentation of amylose in the cecum increases the utilization of undigested nutrients in the small intestine. Therefore, meat rabbits and wool rabbits are considered to have a higher utilization rate of potato starch than other animals.

However, in the potato starch group, meat rabbits and wool rabbits with different starch sources had the lowest endogenous nitrogen losses. Based on this, it can be concluded that the potato starch group has the highest dietary nitrogen utilization rate and the lowest endogenous nitrogen losses. This may be due to the fact that undigested starch in the small intestine is used as energy by the cecal microbiota, recycling endogenous N into microorganisms to provide energy for the body. Since the amylose and corn starch in tapioca starch are relatively low, the rabbit's cecum does not have enough starch to provide energy, which indirectly reduces the nitrogen utilization rate.

Different relative ratios of amylose and amylopectin also affect energy metabolism (Zhang et al., 2017; Cao et al., 2018). In this experiment, rabbits had the highest energy utilization rate in potato starch group and the lowest endogenous energy losses. The straight branch ratio of potato starch is higher than the other two starches. Amylose is degraded more slowly in the small intestine. Starch that has not been degraded by the small intestine enters in the cecum and undergoes microbial fermentation to produce a large number of short chain fatty acids, which is beneficial to animal growth and intestinal health (Liu et al., 2013). The cecum of rabbits can effectively decompose and use amylose to improve the energy utilization rate in feed.

CONCLUSIONS

The potato group had the highest dry matter intake, and rabbits (include meat rabbits and wool rabbits) with the potato starch-type diet had the lowest endogenous nitrogen and energy losses.

ACKNOWLEDGEMENTS

This study was supported by the National Rabbit Industry Technology System of China (CARS-43-B-2).

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