Songklanakarin J. Sci. Technol.
42 (4), 753-758, Jul. - Aug. 2020

http://www.sjst.psu.ac.th

Original Article

Effect of level of cassava pulp in fermented total mixed ration on feed intake, nutrient digestibility, ruminal fermentation and chewing behavior in goats

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Received: 8 June 2018; Revised: 12 October 2018; Accepted: 8 April 2019

Abstract

The objective of this study was to determine the effects of cassava pulp level in fermented total mixed ration (FTMR) on feed intake, nutrient digestibility, chewing behavior, and ruminal fermentation. Four native crossbred goats were randomly assigned in a 4x4 Latin square design. During each of four 21-day periods, the animals were fed four dietary treatments that varied in the levels of cassava pulp: 1) FTMR 0% cassava pulp, 2) FTMR 10% cassava pulp, 3) FTMR 20% cassava pulp, and 4) FTMR 30% cassava pulp. The results showed that feed intake, nutrient digestibility, ruminal fermentation, and chewing behavior were not significantly different among the treatments (P>0.05). The results concluded that cassava pulp can be used in FTMR for goats in levels of 10−30% which had no effect on dry matter intake, nutrient digestibility, ruminal fermentation, or chewing behavior.

Keywords: fermented total mixed ration, feed intake, nutrient digestibility, ruminal fermentation, goats

1. Introduction

The processing of cassava starch produces large amounts of waste and the two major waste products are cassava peel and cassava pulp. Cassava peel and cassava pulp account for 10−13% and 10−15% of tuber weight, respectively (Khempaka, Molee, & Guillaume, 2009; Oladunjoye, Ojebiyi, & Amao, 2010). In Thailand, approximately 1.5−2.0 million tonnes of cassava pulp are produced annually from the entire cassava starch industry (Chauynarong, Bhuiyan, Kanto, & Iji, 2015). Fresh cassava pulp contains approximately 60−75% moisture (Chauynarong *et al.*, 2015), 69.89% starch, 1.55% crude protein, 27.75% crude fiber, and 1.70% ash on a dry matter basis (Sriroth, Chollakup, Chotineeranat, Piyachomkwan, & Oates, 2000). Additionally, the price of cassava pulp is always cheap (≈150 baht/tonne). Therefore, cassava pulp is a potential resource to reduce the cost of animal feed.

However, fresh cassava pulp contains a high moisture content which is not suitable for conventional feed, but there are ways to use cassava pulp by making fermented total mixed ration (FTMR). FTMR is a simple method to use the potential nutrients and extend the shelf life of feed (Wongnen *et al.*, 2009). Furthermore, the high moisture content of the cassava pulp can be used. Also, FTMR can increase feed intake and nutrient digestion (Vasupen *et al.*, 2006; Yuangklang, Vasupen, Wittayakun, Srinanaun, & Sukho, 2004). However, cassava pulp consists of small particles and less physically effective neutral detergent fiber (NDF) that may affect chewing time in goats. There is currently insufficient information regarding FTMR prepared by cassava pulp and its effects in goats. The objectives of this study were

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to determine the effects of cassava pulp level in FTMR on feed intake, nutrient digestibility, chewing behaviors, and ruminal fermentation in goats.

2. Materials and Methods

2.1 Preparation of fermented total mixed ration (FTMR)

The feed stuffs such as cassava pulp, soybean meal, chopped rice straw (1 cm), cassava chip, rice bran, salt, limestone, and mineral mixtures were used as the ingredients in the FTMR. Table 1 shows the FTMR formulations. The ingredients were mixed together and fresh water was added at 50, 15, 10, and 5 liters. The rations were contained in plastic bags and rumen fluid was suctioned by vacuum pump. The FTMR were placed in the shed about 21 days before starting the experiment.

2.2 Animals and feeding

Four male Thai native goats were used with an initial mean body weight of 15.75±2.39 kg. The animals were dewormed using Ivermectin and AD_3E vitamin-complex was injected prior to the beginning of the experiment. The goats were housed in individual pens and fed *ad libitum* at 07:00 and 19:00 h. Drinking water was offered and available at all times. The animals were randomly allocated to one of four treatments in 4x4 Latin square design with 21 day periods. The dietary treatments were the control group (0% cassava pulp), FTMR composed of 10% cassava pulp, FTMR composed of 20% cassava pulp, and FTMR composed of 30% cassava pulp. The experiment was carried out at the Division of Animal Science, Faculty of Technology, Mahasarakham University, Thailand. The animals were weighed at the beginning and at the end of each period.

2.3 Sample collection and preparation

The FTMRs were randomly collected and combined prior to the analyses. The combined samples were ground to pass through a 1 mm screen and analyzed for dry matter (DM), ash, and crude protein (CP) (Association of Official Analytical Chemists [AOAC], 1990), NDF, acid detergent fiber (ADF), acid detergent lignin (ADL) (Van Soest, Robertson, & Lewis, 1991), and acid insoluble ash (AIA) (Van Keulen & Young, 1977).

Fecal samples were collected by grab sampling at 10:00 h on three consecutive days and combined. The feces were placed in an oven at 65 °C for 72 h, weighed and ground to pass through a 1 mm screen and then analyzed for DM, ash, CP, NDF, ADF, and AIA. The chemical composition of the feed and feces were estimated for nutrient digestibility using AIA as the internal marker (Schneider & Flatt, 1975).

Rumen fluid (15 mL) was collected at the end of each sampling period at 4 h post-feeding by stomach tube connected with a vacuum pump. Ruminal pH was measured immediately after sampling using a pH meter (Handy Lab 1, CG842 Schott). Rumen fluid samples were then filtered through four layers of cheesecloth. Fifteen milliliters of rumen fluid was acidified with 1.5 mL of 6 N HCl and centrifuged at 16000*g* for 15 min and the clear supernatant was stored in plastic tubes at −20 °C until analyzed for rumen ammonia nitrogen using the micro-Kjeldahl methods.

On day 19 and 20 of each period, the chewing behaviors and activities after rumination chew were monitored visually at all times. The total chewing time was calculated by the sum of eating time and ruminating time. Eating chew and ruminating chew were measured by counting according to Chumpawadee and Pimpa (2009).

2.4 Statistical analysis

A 4x4 Latin square design with four animals, four periods was carried out in this experiment. Each period consisted of 21 days (14 days for adaptation and 7 days for sample collection). All data obtained from the experiment were subjected to the analysis of variance procedure of Statistical Analysis System (SAS, 1996). The means were separated by Duncan’s New Multiple Range Tests. Significance was determined at $P<0.05$.

3. Results and Discussion

3.1 Chemical composition of dietary treatment

The chemical compositions of the dietary treatments are presented in Table 1. All diets had a similar chemical composition except for differences in the NDF and ADF. The increasing levels of cassava pulp in the FTMR resulted in higher NDF and ADF contents because cassava pulp has high

Table 1. Feed formulation and chemical composition of dietary treatments.

Ingredients	Levels of cassava pulp			
	0%	10%	20%	30%
Cassava pulp	0.00	10.00	20.00	30.00
Soybean meal	15.00	15.00	15.00	15.00
Rice straw	15.00	15.00	15.00	15.00
Cassava chip	45.00	35.00	25.00	15.00
Cane molasses	5.50	5.50	5.50	5.50
Rice bran	18.00	18.00	18.00	18.00
Salt	0.50	0.50	0.50	0.50
Limestone	0.50	0.50	0.50	0.50
Mineral mixed	0.50	0.50	0.50	0.50
Total	100.0	100.0	100.0	100.0
Chemical composition				
DM, %	94.88	95.75	95.13	94.23
Ash, %	7.91	8.18	8.00	6.57
CP, %	10.45	11.76	9.17	9.33
NDF, %	18.88	21.45	26.77	27.48
ADF, %	15.91	19.69	22.64	24.67
ADL, %	5.45	3.82	4.43	4.73
Total digestible nutrient* (TDN), %	74.34	72.94	71.54	70.14
Calcium*, %	0.43	0.47	0.51	0.56
Phosphorus*, %	0.34	0.33	0.33	0.32

*Calculated value
DM=dry matter, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL=acid detergent lignin, TDN=total digestible nutrients.

levels of NDF and ADF (Pilajun & Wanapat, 2016). The CP content in the FTMR treatments had similar calculated values and met the requirement for goats. Collectively, these observations indicated that the FTMR treatments used in this study were within the normal ranges in nutritional aspects and fermentation characteristics.

3.2 Feed intake and nutrient digestibility

Feed intake in terms of kg/day, percent body weight (%BW) and g/kg $BW^{0.75}$ are presented in Table 2. Many dietary factors may influence dry matter intake in a ruminant such as physical characteristics, ingredients, and nutrient composition. In this study, dry matter intake was not influenced by the levels of cassava pulp in the FTMR. This is because cassava pulp is palatable and has good physical characteristics. Additionally, the FTMR had a sour taste which is preferred by ruminants. Therefore, the cassava pulp levels in the FTMR did not affect the feed intake.

Digestibility of DM, organic matter (OM), NDF, and ADF were not significantly difference between treatments (P>0.05) (Table 2). The results showed that the different levels of cassava pulp did not affect nutrient digestibility of the FTMR which implied that the animals had similar nutrient uptake. It is noticeable that nutrient digestibility in all treatment was high which agreed with Yuangklang *et al.* (2004) who suggested that FTMR can increase feed intake and nutrient digestion. However, many factors may influence nutrient digestibility, such as protein levels, protein sources, and protein fraction (Kawashima *et al.,* 2003; Milis & Licmalis, 2007). Moreover, the ratio of rumen undegradable protein to rumen degradable protein, animal condition, breed, sex, non-structural carbohydrate (Chantiratikul *et al.,* 2009) and proportion of lignified cell walls (Chumpawadee & Pimpa, 2008) also affected nutrient digestibility. Even though all of the FTMR treatments had different levels of cassava pulp, they were all similar in nutrient compositions and the levels of cassava pulp did not affect nutrient digestibility.

Table 2. Effects of level of cassava pulp in fermented total mixed ration on voluntary feed intake, nutrient digestibility, and ruminal fermentation in goats.

Parameters	Level of cassava pulp				SEM
	0%	10%	20%	30%	
Dry matter intake					
Kg/day	0.59	0.64	0.69	0.53	0.03
%BW	3.44	3.56	3.09	3.07	0.11
$g/kgBW^{0.75}$	70.18	73.42	63.94	62.70	2.28
Nutrient digestibility					
DMD	62.53	67.95	67.86	61.10	3.03
OMD	67.60	72.65	71.46	64.67	2.77
CPD	55.46	64.55	55.86	60.75	3.47
NDFD	48.26	49.27	52.03	55.85	2.15
ADFD	43.23	45.57	46.46	43.20	2.68
Ruminal fermentation					
pH	6.30	6.47	6.60	6.70	0.15
NH_3-N, mg%	9.43	9.72	9.00	9.90	0.76

BW=body weight, DMD=dry matter digestibility, OMD=organic matter digestibility, CPD=crude protein digestibility, NDFD=neutral detergent fiber digestibility, ADFD=acid detergent fiber digestibility, NH_3-N=ammonia nitrogen.

3.3 Ruminal fermentation

The concentrations of ruminal ammonia-nitrogen (NH_3-N), and the pH in the rumen fluid were used to monitor the ruminal fermentation pattern. The ruminal pH values at 4 h post-feeding are presented in Table 2. The mean values of ruminal pH did not differ significantly at any level of cassava pulp in the FTMR (P>0.05). The ruminal pH values were relatively within the normal range of 6.30−6.70 and all mean values were within the reported optimal pH range of 6.0−7.0 for microbial digestion of protein (Hoover, 1986) and fiber digestion (Theodorou & France, 1993). Rumen pH decreases when diets contain an abundance of soluble carbohydrates (Sutter & Beever, 2000). Generally, the rate and extent of carbohydrate degradation is influenced by the ruminal pH (Nocek & Russell, 1988). A large amount of soluble carbohydrates may reduce the pH of ruminal fluid and this can affect the rate of fermentation of structural carbohydrates (Sutton & Alderman, 2000). In addition, ruminal pH is partly regulated by the concentration of NH_3-N (Chanjula, Wanapat, Wachirapakorn, & Rowlinson, 2004) and volatile fatty acid concentration in the rumen (Stokes, Hoover, Miller, & Blauweikel, 1991). However, all treatments in this experiment were similar in chemical composition; therefore, the ruminal pH was similar in all treatments. Moreover, all treatments had rice straw as the source of roughage at about 15%. Since rice straw has the properties of an effective fiber, it was expected that the rice straw would have a positive effect on chewing activity that led to normal rumen conditions and digestion.

Ruminal NH_3-N at 4 h post-feeding is presented in Table 2. The results showed that the level of cassava pulp in FTMR did not alter ruminal NH_3-N concentration. Ruminal NH_3-N is produced by protein degradation in the rumen. Rumen microorganisms metabolize protein, peptides, and amino acids in the rumen to NH_3-N. Since the diets in this experiment were isonitrogenous, the NH_3-N concentrations were similar in all treatments. Ammonia nitrogen is the major end product of protein degradation and used by the majority of rumen bacteria to synthesize bacterial protein (Bava, Rapetti, Crovetto, & Tamburini, 2001). Ammonia nitrogen is the preferred nitrogen source for fiber digesting bacteria and ammonia nitrogen is also required for starch, sugar, and secondary rumen fermentation for protein synthesis (Song & Kennelly, 1990). Inadequate N supplies for rumen microbial activity has a negative effect on the degradation of the other dietary components, particularly in diets rich in cellulose. The suggested optimum ammonia concentration for microbial growth was in the range of 5−8 mg% (Satter & Slyter, 1974). In this study, the range of NH_3-N was 9.0−9.90 mg%. In this study, the ruminal NH_3-N levels were within the optimum levels for microbial protein synthesis, rumen ecology, and microbial activity (Wanapat & Pimpa, 1999).

3.4 Chewing behavior

Chewing time (min/day) at eating and ruminating, eating rate (gDM/min), and rumination efficiency (gDM/min) were not significantly different (P>0.05) among the treatments (Table 3). However, chewing times in terms of min/kgNDF

Table 3. Eating and ruminating behavior, ruminated boli and boli characteristics in goat fed difference fermented TMRs.

Parameters	Level of cassava pulp				SEM
	0%	10%	20%	30%	
Chewing time, min/day					
Eating	261.20	176.63	233.63	205.82	23.12
Rumination	149.33	142.08	148.30	153.89	13.65
Total	410.53	318.70	381.93	359.71	31.61
Chewing time, min/kg NDF intake					
Eating	2497.80	1261.00	1246.60	1467.20	246.64
Rumination	1397.30	1042.50	822.30	1015.60	117.10
Total	3895.10[a]	2303.60[ab]	2068.90[b]	2482.70[ab]	340.14
Eating rate, g DM/min*	2.83	3.72	3.46	2.87	0.30
Rumination efficiency, gDM/min**	4.40	4.92	5.10	4.20	0.49
No. of chews/day					
Eating	23382.00	15799.00	22368.00	16817.00	2251.64
Rumination	10398.70	9542.80	9076.70	9457.80	916.05
Total	33773.7	25341.80	31444.70	26264.80	2214.68
No. of chews/kg NDF intake					
Eating	224518.0[a]	113337.0[ab]	119901.0[ab]	92507.0[b]	24394.7
Rumination	63594.00	69964.00	48570.00	63243.00	9425.00
Total	321446.00	183301.00	168471.00	180499.00	29910.0
No. of chews/min eating time	90.57	89.20	96.17	80.85	4.34
No. of chews/min rumination time	71.23	66.37	58.56	63.45	2.86
Ruminated boli, no./day	181.00	162.75	142.33	179.50	13.94
Runimated boli, no./kg NDF intake	1693.70[a]	1187.70[ab]	767.60[b]	1235.70[ab]	151.22
No. of chews/bolus	57.66	61.90	61.35	54.85	5.03
No. of boli/min rumination time	1.23	1.17	1.03	1.25	0.09

[a, b, c, d] Means within a row different superscripts differ (P<0.05)
* = DM intake (g/day)/ eating time (min/day).
** = DM intake (g/day)/rumination time (min/day)
NDF=neutral detergent fiber, DM=dry matter.

were significantly different among the treatments (P<0.05). The control group (0% cassava pulp in FTMR) had the highest chewing time. In contrast, the goats that consumed 10%, 20%, and 30% cassava pulp in FTMR had low chewing times in terms of min/kgNDF. This was probably due to the small particle sizes of the cassava pulp that resulted in less physically effective NDF and may have affected the chewing time. This result agreed with Grant *et al.* (1990) who reported that chewing time decreases as the dietary particle size decreases. Even though the chewing time in terms of min/kgNDF decreased, it did not affect the feed intake nutrient digestibility and ruminal fermentation. Moreover, goats kept in individual housing had lower frequency of eating and ruminating time than goats kept in colony housing (Panjone & Agus, 2014). Additionally, Hooper and Welch (1993) suggested that body size affected chewing efficiency. Jang *et al.* (2017) reported that the chewing time of Korean native goats ranged from 248.7 to 297.2 min/day, but in this experiment the chewing time of native Thai goats ranged from 318.7 to 410.5 min/day. The chewing times are different due to breed, body size, dietary particle size, and housing conditions.

The number of chews/day of eating and ruminating, number of chews per kg NDF intake of rumination, number of chews per min eating time, number of chews per min ruminantion time, ruminated boli, number of chews per bolus, and the number boli per rumination time were not significantly different (P>0.05) except for the number of chews per min eating time and ruminated boli in terms of no./kg NDF intake (Table 3). The number of chews was the highest when the goats were fed 0% cassava pulp in the FTMR. However, chewing time and the number of chews were in the normal range. The results suggested that cassava pulp did not negatively affect chewing activity when the amount of cassava pulp was 10−30% in the FTMR. Generally, chewing activity is affected by the effective fiber in the ration (National Research Council [NRC], 1989). This experiment used rice straw as roughage which is high in effective fiber. Therefore, all treatments had normal chewing and ruminating activity.

4. Conclusions

It can be concluded that cassava pulp can be used in FTMR for goats in a concentration range of 10−30% which did not affect dry matter intake, nutrient digestibility, ruminal fermentation, or chewing behavior.

Acknowledgements

The authors would like to express their gratitude to all staff personnel and my students for their invaluable help at the farm and in the laboratory. We are grateful to the Division of Animal Science, Faculty of Technology, Mahasarakham University for supplying the experiment facilities. Financial support was provided by the Faculty of Technology.

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