Growth, Feed Efficiency, Behaviour, Carcass Characteristics and Meat Quality of Goats Fed Fermented Bagasse Feed

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ABSTRACT : The effects of long-term feeding of diets based on bermudagrass hay supplemented with lucerne hay cube (LH) or fermented bagasse feed (FBF) on the growth rate, feed efficiency, behaviour, gut development, carcass characteristics and meat quality of goats were investigated. Six spring-born 8-month-old male crossbred (Japanese Saanen×Tokara native goats) bucks weighing mean 21.6 kg were allotted to 2 treatment groups (3 animals each) and each animal had *ad libitum* access to feeds, i.e. bermudagrass hay (basal diet)+LH or FBF throughout the experiment. The FBF was produced by the solid-state fermentation of substrates containing dried sugarcane bagasse mixed with wheat bran in a ratio of 1:3 (w/w DM) with *Aspergillus sojae*. The live body weight, final weight and average daily gain were not different between treatments. Average basal diet intake of goats fed FBF diet was significantly higher than that fed LH diet ($p<0.05$), but average dry matter intake (DMI; g/day and g/$W^{0.75}$), feed conversion ratio, digestible crude protein (DCP) and total digestible nutrients (TDN) intake of experimental diets were not significantly different between treatments. Goats fed on LH and FBF diets had similar eating, rumination, resting and drinking behaviours, and blood constituents except for phosphorus content. Slaughter and carcass weights, net meat percentage [(total meat/carcass weight)×100], loin ratio [(loin/total meat)×100] and rib-eye area were not different between treatments. However, goats fed FBF diet had lower dressing percentage and higher bone/muscle ratio compared with goats fed LH diet ($p<0.01$). Empty gut and guts fill of goats fed FBF diet were significantly greater ($p<0.05$ and $p<0.01$, respectively) than those fed LH diet. The weights of rumen and abomasum were also significantly heavier in goats fed FBF diet ($p<0.05$), but the length and density of papillae of rumen in goats were not different between treatments. Although meat composition of loin was not different in both groups, the meat of goats fed FBF diet was superior to that of LH diet in flavor, aroma and overall quality of loin ($p<0.01$). In conclusion, the nature of the diet consumed voluntarily did not affect subsequent growth, nutrient intake and behaviour of goats but had an influence on carcass traits and sensory evaluation of meat partly, when either of LH or FBF was fed with bermudagrass hay. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 11 : 1594-1599)***

Key Words : Goats, Growth, Feed Efficiency, Behaviour, Fermented Bagasse Feed, *Aspergillus sojae*

INTRODUCTION

Developing a feeding system using crop residues or agro-industrial by-products will not only lower the cost of animal feed and improve the economic efficiency of animal production. but also reduce the environmental pollution caused by the disposal of these organic wastes (Kajikawa. 1996). Preston et al. (1985) reported that improving the nutritional value of by-products by various treatments has been undertaken since the beginning of 20th century. when a lot of efforts have been geared to treat them by physical, physio-chemical. chemical or biological means. Such treatments degrade the structural carbohydrates of the cell wall and enhanced the digestibility of crop residues. Recently. Tengerdy (1996) and Pandey et al. (2000) have reviewed utilization of agro-industrial by-products such as sugarcane bagasse after their solid-state fermentation (SSF). Bagasse is a fibrous sugarcane by-product containing high fiber (43%) and low nitrogen (0.2%), which has limited use in animal feeds without any proper treatment (Ramli et al.. 2005). A little information is available on the treatment of bagasse and its usage in animal feed, apart from steam treatment and microbial fermentation process (Preston and Leng. 1984; Wan Mohtar and Massadeh. 2003). Bagasse is considered to be an ideal substrate for application in the microbial fermentations for the production of value-added products because of its rich organic content (Zadrazil and Puniya, 1995).

Results of a previous study indicated that the fermentation of bagasse feeds (combination mixture of bagasse with wheat bran) by various Japanese *koji* (genus Aspergillus). can improve the fiber digestion of bagasse (Ramli et al.. 2005). Among 3 strains of the Aspergillus (*Aspergillus oryzae*. *A. sojae* and *A. awamori*). *A. sojae* has more ability to enhance the digestion of NDF. ADF and cellulose of fermented bagasse feed (FBF). However. the long-term effects of FBF feeding on animal performance and physiological response have not been investigated yet. In this context, it is assumed that the microbial fermentation of sugarcane bagasse mixed with wheat bran in the SSF using *A. sojae* can be a technique in upgrading the nutritional value of bagasse as ruminant feed. Therefore. the objective

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Table 1. Chemical composition and nutritive value of bermudagrass hay, lucerne hay cube and fermented bagasse feed

Item (% DM)	Bermudagrass hay	LH	FBF
DM	92.1	91.8	87.7
OM	89.4	85.7	96.6
CP	11.5	18.0	15.6
EE	2.4	2.3	2.9
Ash	10.6	14.3	3.4
NFE	49.0	40.2	61.3
NDF	68.9	40.1	49.3
ADF	31.6	29.5	19.6
Ca	0.5	1.3	0.1
P	0.3	0.4	0.5
Mg	0.2	0.3	0.2
DCP	7.6	13.8	11.9
TDN	58.0	57.9	64.3
DE (Mcal/kg)	2.4	2.5	2.9

LH = Lucerne hay cube; FBF = Fermented bagasse feed; DM = Dry matter; OM = Organic matter; CP = Crude protein; EE = Ether extract; NFE = Nitrogen free extract; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; DCP = Digestible crude protein; TDN = Total digestible nutrients; DE = Digestible energy.

DCP, TDN and DE of FBF were adopted from Ramli et al. (2005).

Table 2. Growth rate, DM intake and feed efficiency of goats fed LH or FBF diet

Item	Diets		SEM
	LH	FBF	
Experimental period (days)	196	196	
Initial weight (kg)	21.4	21.8	1.9
Final weight (kg)	39.3	40.4	1.7
Average daily gain (g/day)	91.3	94.9	10.9
Bermudagrass hay intake (g DM/day)	248.0^{b}	539.7^{a}	71.8
Experimental diet intake (g DM/day)	901.1	710.8	114.3
NDF intake (g DM/day)	532.2^{d}	722.3^{c}	19.9
Total DMI (g/day)	1,149.1	1,250.5	56.4
Total DMI (g/W$^{0.75}$)	42.7	45.1	1.6
Feed conversion ratio (intake/gain)	13.0	13.3	1.1
DCP intake (g DM/day)	143.2	125.6	11.0
TDN intake (g DM/day)	665.6	770.0	32.7

Means in rows with different superscripts differ significantly ($^{a, b}p<0.05$, $^{c, d}p<0.01$). LH = Lucerne hay cube; FBF = Fermented bagasse feed; SEM = Standard error of mean deviation; NDF = Neutral detergent fiber; DCP = Digestible crude protein; TDN = Total digestible nutrients.

The intakes of NDF, DCP and TDN were calculated from daily DM intake (DMI) of each goat, chemical composition and digestibility throughout the experiment.

of this study was to examine effects of long-term feeding of diets based on bermudagrass hay supplemented with lucerne hay cube or FBF on growth rate, feed efficiency, behaviour, gut development, carcass characteristics and meat quality of goats.

MATERIALS AND METHODS

Location and climate of the study area

The study was carried out over a 28-week period between January and July 2004 at the livestock house of the Faculty of Agriculture, Kagoshima University (N31°63 latitude and E130°27 longitude). The climate is a subtropical with short, mild winters and hot, humid summers with average annual rainfall of about 2,240 mm and the mean temperature ranges from 7 to 28°C. The indoor temperature of the livestock house ranged from -2°C (minimum) to 38°C (maximum) and the relative humidity from 13% (minimum) to 99% (maximum) throughout the experiment.

Animal, feeds and management

Six spring-born 8-month-old crossbred (Japanese Saanen×Tokara native goats) bucks, with an average initial body weight (BW) of 21.6±3.0 kg were used in this experiment. The bucks were blocked by their BW and allotted to two feeding regimes. They were kept individually in cages. At the beginning of the adjustment period, they were treated against internal- and ecto-parasites using Ivomec (Ivermectin: 1 ml/10 kg BW) (Ivomec Topical, Merck & Co., Inc.).

Commercial bermudagrass hay (basal diet) and lucerne hay cube (LH) were used in this study. The FBF was produced by the SSF of substrates containing dried sugarcane bagasse mixed with wheat bran in a ratio of 1:3 (w/w DM) in the *koji*-type tray bioreactor. Before loading to the tray (wooden type), 540 ml of tap water was added to the total of 1,336 g (1,200 g DM) of substrates in order to adjust their moisture content to 36% and after sterilization (120°C, 21 min) and cooling to 32°C, 1.2 g of spawn of *Aspergillus sojae* (0.1% DM basis) in powder form was aseptically spread over the substrates and they were mixed well. This material was fermented for 3 days at 30°C. Mixing and aeration of substrates were done manually for at least twice a day in order to achieve uniform fermentation. Chemical composition of feeds used in the experiment is presented in Table 1.

Bucks were fed bermudagrass hay supplemented either with LH or FBF *ad libitum*. Bucks were fed at 09:00 and 17:00 h, daily. Feed offered and refused were recorded daily (before morning feeding) after the adjustment period. Mineral lick blocks and water were available for the animals at all times throughout the experiment. Because of lower Ca/P ratio in the current FBF, 2% of calcium carbonate was added to the ration so that the ratio could be more than 2 and urinary calculi could not occur due to this imbalance.

Measurements

Feed consumption was recorded daily over the 28-week experimental period and body weight was measured at 2-week intervals before morning feeding. Feed samples were collected every 2-week for dry matter (DM) determination. The average daily DM intake (DMI) and average daily gain (ADG) for each goat were calculated from feed consumption data and BW measurements, respectively every 2 weeks throughout the whole period of this study. The average feed conversion (FC) for each goat was calculated as DMI/ADG. In the behavioural observation, the duration of eating, rumination (standing or lying), resting (standing or lying) and drinking behaviours was recorded at 1-min interval during 24 h on the 75-d. Day time was defined as 06:00 to 18:00 h and night from 18:00 to 06:00 h.

Blood constituents

On the final day of the experiment, blood samples were taken in 12 ml tubes from the jugular vein of each buck before the morning feeding. Hematocrit was estimated from the blood sample after centrifugation. Hemoglobin was determined directly from the blood sample using Sysmex F-520 (FUJIFILM, Japan), and glucose, urea nitrogen, Ca, P, Mg contents and the activity of transaminases (alanine aminotransaminases-ALT, aspartate aminotransaminases-AST) were determined from the blood serum using Fuji Dry Chem 3,500 V autoanalyser (FUJIFILM, Japan).

Slaughtering procedure and measurements

At the end of 28 weeks of feeding trial, all goats were slaughtered after fasting for 6 h. Warm carcass of each animal was weighed immediately after dressing and removal of offal parts. Carcasses were chilled at 4°C for 48 h and then weighed to determine the dressing percentage.

Cold carcass was separated into right and left sides. The left carcass half was cut across the 12th rib and the GR value as an indicator of carcass fatness (the depth of muscle and fat tissue from the surface of the carcass to the lateral surface of the 12th rib 110 mm from the midline) was directly measured using a GR knife as described by Pi et al. (2005). Rib-eye area was measured after ribbing between the 6th and 7th ribs. The carcass was then cut into pieces and dissected in fat, muscles, bones and skin. The weights of liver and kidneys were recorded. An approximately 100 g sample from loin muscles of each carcass was stored at -20°C for later chemical analysis. Gut (stomach complex) contents were calculated as the difference between the full and empty gut. Washed guts were then separated into four parts described as rumen, reticulum, omasum and abomasum, and their weights were recorded. Samples (triplicate) of rumens (*Saccus ventralis*) were taken by cutting in a size of 1 cm^2 (from their lower portion) each to examine the length and total number of papillae contained. The length (the distance from the tip to the base of papillae) and the number (the total number of papillae per unit area) of papillae were observed under naked eye. Samples of loin and leg muscles were taken from the right carcass half of each goat for sensory evaluation. Thirty six evaluators (average age of 24 years) were gathered together and each evaluator was served a slice of chevon grilled using a hot plate for loin and leg samples. A 5-point hedonic ballot was used for the sensory evaluation based on the following index: flavor, aroma, tenderness, juiciness and overall quality as described by AMSA (1978). Judges used a hedonic scale for evaluating samples ranging from 5 (like extremely) to 1 (dislike extremely).

Chemical analysis and digestion trial

All analyses were done in triplicate. Dry matter (DM) was determined by oven drying at 60°C for 48 h. Proximate analysis of feed samples was carried out for organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF) and ash was conducted on oven-dried feed, and that of minced samples of loin muscle was also done for moisture, CP, EE and ash contents according to the methods of AOAC (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents of the feeds were analyzed according to the method described by Goering and Van Soest (1970). Energy value of both feeds and loin muscle was determined using an adiabatic bomb calorimeter (Shimadzu CA-4PJ type, Shimadzu Co., Ltd.). *In vivo* digestibilities of nutrient of bermudagrass hay and LH were determined separately or in combination using 3 Nubian does according to the digestion trial of Ramli et al. (2005) to calculate digestible crude protein (DCP), total digestible nutrients (TDN) and digestible energy (DE) contents. The DE was calculated by the subtraction of energy loss into feces from energy value in feed. The chemical composition, DCP, TDN and DE of the FBF were described in Ramli et al. (2005).

Statistical analysis

All data except for data on sensory evaluation were analyzed by a one-way analysis of variance (ANOVA) and tested using Fisher's PLSD test, while the sensory evaluation was made by the Wilcoxon's signed rank test, performed with a StatView for Windows (SAS, 1992).

RESULTS

Growth rate

The BW of goats fed bermudagrass hay supplemented with either LH or FBF was not significantly different (Table 2). However, growth rate for LH and FBF was slow or negative from 18 to 20 weeks as shown in Figure 1. There were no significant differences in BW between treatments throughout the experiment. There were no significant differences in final weight and ADG between treatments (Table 2).

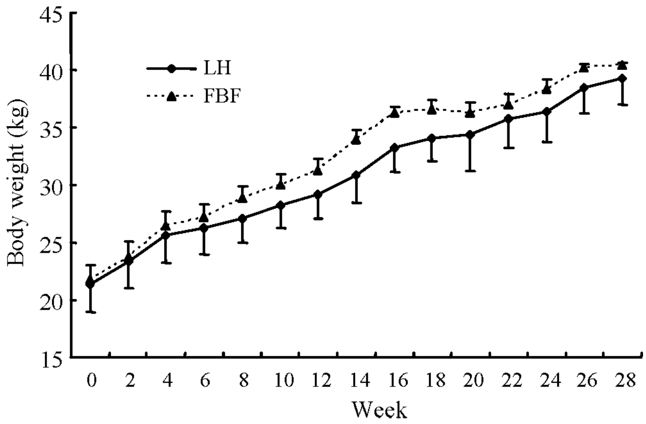

Figure 1. Changes in live body weight of goats fed LH (lucerne hay cube+bermudagrass hay) or FBF (fermented bagasse feed+bermudagrass hay) diet over the experimental period.

Table 3. Time budget of daily maintenance behaviours of goats fed LH or FBF diet

Item	Diets		SEM
	LH	FBF	
	------------ % ----------		
Eating (basal diet)	4.1	7.8	2.5
Eating (experimental diet)	15.8	16.5	3.4
Rumination*	62.6	59.9	4.0
Resting*	7.9	5.7	0.6
Drinking	1.0	0.9	0.2
Others**	8.6	9.1	1.5
Eating activities			
Duration (min/day time)	212.0	272.0	27.3
Duration (min/night)	74.7	78.3	13.8
Total duration (min/day)	286.7	350.3	40.8
Rumination activities			
Rum. (min/day time)	169.0	154.3	15.3
Rum. (min/night)	219.7	209.3	17.6
Total rumination (min/day)	388.7	363.7	27.1

* Including standing or lying.

** Including oral activities, self grooming and excretion etc.

Feed efficiency

The average bermudagrass hay and NDF intake of goats fed FBF diet was significantly higher than those fed LH diet ($p<0.05$ and $p<0.01$, respectively). However, there were no significant differences in average DMI (g/day and g/$W^{0.75}$) of the experimental diets, feed conversion ratio, DCP and TDN intake between treatments.

Behaviour

There were no significant differences in eating, rumination, resting and drinking behaviours of goats fed on LH and FBF diets (Table 3). About 70 to 80% of the eating time spent by goats in both groups was in day time. Feeding duration and rumination per day of goats were not different between treatments.

Table 4. Blood constituents of goats fed LH or FBF diet

Item	Diets		SEM
	LH	FBF	
Hematocrit (%)	38.0	38.0	1.8
Hemoglobin (g/dl)	13.5	13.5	0.6
Glucose (mg/dl)	50.0	38.0	3.9
Blood urea nitrogen (mg/dl)	26.0	23.7	1.4
Alanine aminotransaminase (IU/l)	17.3	24.3	3.5
Aspartate aminotransaminase (IU/l)	81.0	94.0	8.4
Ca (mg/dl)	10.7	10.2	0.1
P (mg/dl)	6.9[b]	11.0[a]	0.5
Mg (mg/dl)	2.5	2.7	0.1

[a, b] Means in rows with different superscripts differ significantly ($p<0.01$).

Table 5. Carcass traits of goats fed LH or FBF diet

Item	Diets		SEM
	LH	FBF	
Slaughter weight (kg)	39.3	40.4	1.7
Carcass weight (kg)	19.1	17.6	0.8
Dressing percentage	48.8[a]	43.5[b]	0.3
Net meat percentage*	61.5	62.1	0.4
Bone/muscle ratio	0.2[b]	0.3[a]	0.03
Loin ratio** (%)	7.8	7.1	0.3
Rib-eye area (cm^2)	7.4	7.4	0.5
GR*** (mm)	15.5	10.2	1.4
Liver weight (g)	534.7	540.3	51.2
Kidney weight (g)	129.0	117.5	4.8
Skin weight (kg)	1.4	1.3	0.1

[a, b] Means in rows with different superscripts differ significantly ($p<0.01$).

* (Total meat/carcass weight)×100.

** (Loin/total meat)×100.

*** The depth of muscle and fat tissue from the surface of the carcass to the lateral surface of the 12th rib 110 mm from the midline (Pi et al., 2005).

Blood constituents

Blood P content of goats fed FBF diet was significantly higher than those fed LH diet ($p<0.01$), but there was no significant difference for other blood constituents of goats fed either LH or FBF diet (Table 4).

Carcass characteristics

Carcass traits of goats fed LH and FBF diets are presented in Table 5. Slaughter and carcass weights, net meat percentage [(total meat/carcass weight)×100], loin ratio [(loin/total meat)×100], rib-eye area and skin weight were not significantly different between treatments. The GR indicative of carcass fatness for goats fed LH diet tended to be higher than that on FBF diet ($p<0.1$). However, goats fed FBF diet had lower dressing percentage and higher bone/muscle ratio compared with goats fed LH diet ($p<0.01$). The weights of liver and kidney were not different between treatments.

Gut characteristics

Gut characteristics of goats fed LH and FBF diets are shown in Table 6. Empty gut and gut fill of goats fed FBF

Table 6. Gut characteristics of goats fed LH or FBF diet

Item	Diets		SEM
	LH	FBF	
Empty gut (kg)	0.9^{b}	1.2^{a}	0.1
Gut fill (kg)	4.7^{d}	7.6^{c}	0.2
Rumen weight (g)	597.7^{b}	776.3^{a}	41.2
Reticulum weight (g)	93.7	100.3	7.5
Omasum weight (g)	86.7	121.0	12.5
Abomasum weight (g)	139.7^{b}	201.3^{a}	14.6
Papillae characteristics of rumen			
Length (mm)	4.3	4.3	0.6
Density (no./cm^2)	54.7	49.3	5.5

Means in rows with different superscripts differ significantly (^{a,b}p<0.05, ^{c,d}p<0.01).

diet were significantly greater than those fed LH diet (p<0.05 and p<0.01, respectively). The weights of rumen and abomasum were also significantly heavier with FBF diet (p<0.05). In contrast, the weights of reticulum and omasum, length and density of papillae of rumens were not significantly different between treatments.

Meat quality

Loin meat composition was not different in goats fed either LH or FBF diet (Table 7). The meat of goats fed FBF diet was superior to that on LH diet in flavor, aroma and overall quality of loin (p<0.01), and in flavor of leg (p<0.05).

DISCUSSION

As presented in Figure 1, goats in both LH and FBF groups had temporary slow or negative growth at 18 to 20 weeks, which may be due to higher indoor temperature (over 35°C) in hot summer. Indeed, there was a reduction in feed intake of goats (70 g/day for LH and 250 g/day for FBF) in the 18 to 20 weeks of the experimental period. The effect of heat stress on lowered feed consumption in livestock is widely documented (Tisserand, 1991; Hernandez Ledezma, 1992), which may have reduced the growth rate of goats (Lu, 1989). As shown in Table 2, total DMI and that per $W^{0.75}$ were not different for goats fed either LH or FBF diet, indicating that FBF alternative of LH had no adverse effect on voluntary feed intake by goats. The higher intake of both bermudagrass hay and NDF by goats fed FBF diet appeared to be attributed to the greater ability of fiber digestion by goats fed FBF (Ramli et al., 2005), but this could not lead to the improvement of the growth rate. Kawashima et al. (2003) in their study regarding the use of sugarcane stalk in the diet of cattle reported that the tough fiber of sugarcane stalk might remain in the rumen during a relatively longer period which would depress the consumption. Leng and Preston (1988) also reported that the fiber of sugarcane is slowly digested with its longer

Table 7. Meat composition of loin and sensory evaluation of loin and leg meats of goats fed LH or FBF diet

Item	Loin		Leg	
	LH	FBF	LH	FBF
Moisture (%)	75.6	74.9	-	-
Protein (%)	20.2	20.8	-	-
Fat (%)	2.6	2.7	-	-
Ash (%)	1.4	1.4	-	-
Energy (kcal/g)	1.1	1.1	-	-
Flavor	2.6^{d}	3.6^{c}	2.8^{b}	3.3^{a}
Aroma	2.1^{d}	3.1^{c}	2.6	2.8
Tenderness	3.1	3.1	2.6	2.5
Juiciness	2.9	2.9	2.4	2.5
Overall quality	2.6^{d}	3.4^{c}	2.6	2.9

Means in rows under same category with different superscripts differ significantly (Wilcoxon's signed rank test, ^{a,b}p<0.05, ^{c,d}p<0.01).

retention time in the rumen. Therefore, it is suggested that the higher NDF intake of goats fed FBF diet would be caused by the higher NDF digestion (Ramli et al., 2005), though potentially undegradable fraction (tough fiber) remains in the rumen for a relatively longer time.

Total time spent eating of goats in this study was 5 to 6 h per day, which was similar that was previously reported by Morand-Fehr et al. (1991), Abijaoudé et al. (2000) and Van et al. (2002). In many cases, total time spent eating of goats was highly variable, which depends on feed quality, type and mode of feeding. Van et al. (2002) also reported that approximately 75% of eating time of goats was in day time, which is consistent with the results of the present study (70 to 80%).

Although there was significant difference in blood P contents of goats between LH and FBF diets (Table 4), both values were within the normal range as described by Blood and Studdert (1989). Although the blood glucose content of goats fed either LH or FBF diet was somewhat less than the normal range (Blood and Studert, 1989), no hypoglycemia occurred throughout the experimental period. Moreover, there was no incidence of urinary calculi, suggesting no adverse effect on animal health in this study.

The possible reason for the similar slaughter and carcass weights of goats fed either LH or FBF diet despite the greater bone/muscle ratio and the weights of empty gut and gut fill of goats fed FBF diet is the lower dressing percentage and carcass fatness measured as GR of goats fed FBF diet.

There was no significant difference in fat content of loin between treatments, but the flavor and aroma of meat of goats fed FBF diet were highly evaluated, suggesting some factors associated with meat flavor and aroma. Although a fatty acid is one of the major components affecting meat flavor and aroma, it was not identified in this study. Therefore, further information is needed on the difference in fatty acid composition rather than fat content of goat meat.

It was concluded that the nature of the diet consumed voluntarily did not affect subsequent growth, nutrient intake and behaviour of goats but had an influence on carcass traits and sensory evaluation of meat partly, when offering bermudagrass hay as a basal diet together with lucerne hay cube or FBF.

IMPLICATIONS

This study showed the FBF could be an alternative to lucerne hay cube in goat feeds with little adverse effect on the performance, feed efficiency, animal health and meat quality, when offering bermudagrass hay together. Thereby, it was possible to save the cost of goat feeds and to lead to increased self-sufficiency in animal feeds.

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REFERENCES

Abijaoudé, J. A., P. Morand-Fehr, J. Tessier, P. Schmidely and D. Sauvant. 2000. Diet effect on daily feeding behavior, frequency and characteristics of meals in dairy goats. Livest. Prod. Sci. 64:29-37.

American Meat Science Association (AMSA). 1978. Guidelines for Cookery and Sensory Evaluation of Meat. National Live-stock and Meat Board, Illinois, USA. pp. 1-24.

AOAC. 1990. Official Methods of Analysis. 15th edn. Association of Official Analytical Chemists, Washington, DC.

Blood, D. C. and V. P. Studdert. 1989. Bailliere's Comprehensive Veterinary Dictionary. Bailliere Tindall, London. p. 1124.

Goering, H. K. and P. J. Van Soest. 1970. Forage Fiber Analysis. Apparatus, Reagents, Procedures and Some Applications. Agric. Handbook 379. ARS. USDA, Washington, DC. pp. 1-20.

Hernandez Ledezma, J. J. 1992. Sheep: Bioclimatology and the Adaptation of Livestock, 1st. edn. Elsevier, Amsterdam, The Netherlands. pp. 169-179.

Kajikawa, H. 1996. Utilization of by-products from food processing as livestock feed in Japan. Ext. Bull. August, Food & Fertilizer Technology Center, Taipei. pp. 1-8.

Kawashima, T., W. Sumamal, P. Pholsen, R. Chaithiang and Y. Hayashi. 2003. Ruminal degradation of sugarcane stalk. Asian-Aust. J. Anim. Sci. 16:1280-1284.

Leng, R. A. and T. R. Preston. 1988. Constraints of the efficient utilization of sugarcane and its byproducts as diets for production of large ruminants. In: Sugarcane as feed (Ed. R. Sansoucy, G. Aarts and T. R. Preston) FAO, Rome, Italy. pp. 284-309.

Lu, C. D. 1989. Effect of heat stress on goat production. Small Rumin. Res. 2:151-162.

Morand-Fehr, P., E. Owen and S. Giger-Reverdin. 1991. Feeding Behavior of Goats at the Trough. In: Goat Nutrition. (Ed. P. Morand-Fehr) EAAP, Wageningen. pp. 3-12.

Pandey, A., C. R. Soccol and D. Mitchell. 2000. New developments in solid state fermentation: I. bioprocesses and products. Process Biochem. 35:1153-1169.

Pi, Z. K., Y. M. Wu and J. X. Liu. 2005. Effect of pretreatment and pelletization on nutritive value of rice straw-based total mixed ration, and growth performance and meat quality of growing Boer goats fed on TMR. Small Rumin. Res. 56:81-88.

Preston, T. R. and R. A. Leng. 1984. Supplementation of diets based on fibrous residues and by-products. In: Straw and other fibrous by-products as feed. Elsevier Press, Amsterdam. pp. 373-413.

Preston, T. R., V. L. Kossila, J. Goodwin and S. B. Reed. 1985. Better Utilization of Crop Residues and By-product in Animal Feeding: Research Guidelines 1. State of Knowledge. FAO. Rome. p. 213.

Ramli, M. N., Y. Imura, K. Takayama and Y. Nakanishi. 2005. Bioconversion of sugarcane bagasse with Japanese *koji* by solid-state fermentation and its effects on nutritive value and preference in goats. Asian-Aust. J. Anim. Sci. 18:1279-1284.

SAS. 1992. StartView for windows, Version 5.0. SAS Institute Inc., Cary, North Carolina, USA.

Tengerdy, R. P. 1996. Cellulase production by solid state fermentation. J. Ind. Sci. Res. 55:313-316.

Tisserand, J. L. 1991. Feeding strategy for animal production in warm climates. In: Proceedings of the International Symposium on Animal Husbandry in Warm Climates, Viterbo, Italy, EAAP Publication no. 55:64-72.

Van, D. T. T., I. Ledin and N. T. Mui. 2002. Feed intake and behaviour of kids and lambs fed sugar cane as the sole roughage with or without concentrate. Anim. Feed Sci. Technol. 100:79-91.

Wan Mohtar, W. Y. and M. I. Massadeh. 2003. The production of reducing sugar, cellulase enzyme and ruminant feed from solid substrate fermentation (SSF) of sugarcane bagasse. In: Advance in Materials Processing. (Ed. A. Che Husna, M. Andanastuti and M. I. Ahmad Kamal Ariffin). Ins. Mate. Malaysia. 1:253-254.

Zadrazil, F. and A. K. Puniya. 1995. Studies on the effect of particle size on solid state fermentation of sugar cane bagasse into animal feed using white-rot fungi. Biores. Technol. 54:85-87.