Comparison of Different Alkali Treatment of Bagasse and Rice Straw

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ABSTRACT : A study was conducted to determine the effect of different alkali treatments on changes in chemical composition and on degradability of bagasse and rice straw. This study divided into 2 experiments, the first with bagasse and the second with rice straw. Each experiment comprised 9 treatments which included: untreated control; 3% NaOH; 6% NaOH; 3% urea; 6% urea; 3% NaOH/3% urea; 3% NaOH/6% urea; 6% NaOH/3% urea; 6% NaOH/6% urea. In both experiments, crude protein contents were increased from 2.0 to 12.5 units for bagasse and 3.1 to 13.7 units for rice straw by urea treatments. Ash contents of the treated bagasse and rice straw were increased over the untreated control (1.5-9.7 units for bagasse; 4.2-8.8 units for rice straw). The effects on ether extract, crude fiber, neutral detergent fiber and acid detergent fiber of the treated bagasse and rice straw were variable. Nylon bag degradability of dry matter and crude fiber were increased by treatments applying NaOH and NaOH plus urea but not urea alone. In contrast, the degradability of neutral detergent fiber and acid detergent fiber were reduced compared with the untreated control. From these degradability studies, it can be concluded that the most efficient treatments of bagasse were those treatments with 6% NaOH, followed by treatments with 6% NaOH plus 3% or 6% urea and 3% NaOH plus 3% or 6% urea, respectively. However, when comparison was made on the cost of chemical used to treat the agricultural by-products, particularly in case of rice straw, 3-6% urea would be appropriate. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 10 : 1430-1433)***

Key Words : Bagasse, Rice Straw, Alkali Treatment, Nylon Bag Degradability

INTRODUCTION

Agricultural by-products such as rice straw and bagasse have enough potential to be used as dairy cattle feed in Thailand particularly when forages are in short supply. Although these agricultural by-products are low in protein, palatability and digestibility and thus their nutritive values, the value of exploring increased use of rice straw and bagasse is of considerable importance. The approaches that have been generally tried for using such agricultural by-products are treatments for improving palatability and digestibility to utilize rice straw and bagasse as substitutes for conventional roughages.

Like other agricultural by-products rice straw and bagasse contain lignocellulosic materials. The lignification degree and the present of crystalline cellulose represent a steric barrier that prevents the enzymatic attack of ruminal microorganisms on cellulose and hemicellulose. Rice straw and bagasse, like any other by-products containing high fiber, respond to various treatments. Physical treatments include soaking/wetting, chopping, grinding, pelletting, steaming under pressure and gamma radiation. Alkali, acid and oxidative reagent treatments are kinds of chemical treatments. Biological treatments comprise composting, ensiling, fungal growth and enzyme addition. Details of these procedures have been extensively reviewed (Ibrahim, 1983; SunstØl, 1984; Doyle et al., 1986).

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Most researches mentioned earlier involved the treatments of rice straw with various methods. Cabello (1994) reviewed the treatment of bagasse mainly with chemical processes. The most promising method is alkali treatment with sodium hydroxide. Sodium hydroxide, as a strong alkali, has been mostly used for recalcitrant materials like bagasse and rice straw. A 3-4 fold increase of the initial digestibility value is achieved by applying 5-6% of solid NaOH to the materials on a dry matter basis. However, the results with urea treatment have not been encouraging with bagasse. It is not known why bagasse does not respond to urea treatment like cereal straw. It is probably due to the lack of urease enzyme in bagasse compared with rice straw (Rangnekar, 1988).

The aim of the present study is to determine the effect of various alkali treatments on chemical composition and on nylon bag degradability of bagasse and rice straw.

MATERIALS AND METHODS

Bagasse or rice straw was chemically treated by different methods and two trials involving 9 treatments were conducted. The treatments in each trial consisted of untreated control, 3% NaOH, 6% NaOH, 3% urea, 6% urea, 3% NaOH/3% urea, 3% NaOH/6% urea, 6% NaOH/3% urea and 6% NaOH/6% urea. The experiment was a complete randomized design. The initial moisture content of bagasse was approximately 45% while that of rice straw was approximately 15%. NaOH and/or urea were directly thoroughly mixed with the bagasse prior to fill in airtight

Table 1. Dry matter contents, chemical composition, gross energy contents and nylon bag degradability of untreated and treated bagasse

Trt.	C	T1	T2	T3	T4	T5	T6	T7	T8	SEM
% DM	55.0^{d}	60.6^{c}	63.5^{a}	61.3^{bc}	60.0^{d}	63.6^{a}	63.9^{a}	63.2^{ab}	63.5^{a}	0.9
% ASH	1.5^{f}	7.6^{c}	13.2^{a}	4.4^{de}	3.0^{ef}	6.3^{cd}	6.1^{cd}	11.2^{ab}	10.6^{b}	1.1
% CP	1.4^{e}	1.2^{e}	1.4^{e}	3.4^{d}	8.6^{b}	6.4^{c}	13.3^{a}	7.8^{bc}	13.9^{a}	0.8
% EE	0.35^{b}	0.10^{b}	0.20^{b}	0.40^{b}	0.80^{a}	0.90^{a}	1.00^{a}	0.35^{b}	0.80^{a}	0.2
% NDF	88.5^{a}	82.8^{bc}	75.8^{de}	87.1^{ab}	87.2^{a}	87.0^{ab}	80.1^{cd}	73.9^{e}	72.2^{e}	2.1
% ADF	55.1^{bc}	54.2^{cd}	52.0^{e}	57.6^{a}	56.5^{ab}	53.8^{cde}	52.5^{de}	51.9^{e}	49.3^{f}	1.0
GE	4.20	4.08	3.90	4.20	4.20	4.10	4.00	3.90	3.80	NA
48 h degradation (%)										
DM	24.4^{d}	33.1^{c}	46.0^{a}	23.0^{d}	24.1^{d}	37.5^{b}	38.6^{b}	38.8^{b}	40.9^{a}	2.0
CF	22.1^{cde}	25.6^{bcd}	36.0^{a}	19.6^{e}	21.1^{de}	29.6^{b}	28.3^{b}	27.2^{bc}	30.1^{b}	2.6

DM: dry matter; CP: crude protein; EE: ether extract; CF: crude fiber; NDF: neutral detergent fiber.
ADF: acid detergent fiber; GE: gross energy (Mcal/kg DM); NA: not available.

Table 2. Dry matter contents, chemical composition, gross energy contents and nylon bag degradability of untreated and treated rice straw

Trt.	C	T1	T2	T3	T4	T5	T6	T7	T8	SEM
% DM	92.0^{a}	73.5^{bc}	72.0^{cd}	73.6^{bc}	72.4^{bcd}	70.2^{d}	72.2^{bcd}	73.4^{bc}	74.4^{b}	1.1
% ASH	10.8^{c}	18.3^{ab}	19.6^{a}	16.7^{c}	15.0^{d}	17.4^{bc}	17.0^{c}	18.3^{b}	17.7^{bc}	0.6
% CP	2.3^{e}	2.7^{e}	2.3^{e}	5.4^{d}	10.6^{c}	9.7^{c}	15.9^{a}	8.7^{c}	14.0^{b}	0.7
% EE	1.02^{ab}	0.87^{bc}	0.59^{d}	0.58^{d}	0.63^{cd}	0.44^{de}	0.34^{e}	1.16^{a}	1.12^{a}	0.1
% CF	32.5^{bc}	34.1^{a}	33.5^{ab}	33.6^{ab}	32.5^{bc}	31.4^{cd}	30.3^{d}	30.3^{d}	30.8^{d}	0.7
% NDF	70.5^{a}	66.9^{bc}	59.9^{d}	70.1^{ab}	68.3^{ab}	64.5^{c}	60.9^{d}	59.0^{d}	58.6^{d}	1.7
% ADF	39.8^{ab}	38.7^{bc}	36.7^{d}	40.2^{ab}	41.0^{a}	39.8^{ab}	37.1^{cd}	36.7^{d}	36.9^{cd}	0.9
GE	3.60	3.34	3.18	3.44	3.49	3.36	3.28	3.24	3.20	NA
48 h degradation (%)										
DM	39.9^{d}	54.4^{a}	57.3^{a}	54.3^{a}	46.5^{c}	31.9^{e}	36.3^{de}	48.6^{bc}	53.0^{ab}	2.4
CF	31.2^{d}	52.9^{a}	51.1^{ab}	55.4^{a}	45.7^{bc}	29.4^{d}	31.5^{d}	35.2^{d}	42.3^{c}	3.0

DM: dry matter; CP: crude protein; EE: ether extract; CF: crude fiber; NDF: neutral detergent fiber.
ADF: acid detergent fiber; GE: gross energy (Mcal/kg DM); NA: not available.

polyethylene bags (approx. 1 kgDM of bagasse per bag). However, with rice straw NaOH and/or urea were dissolve in water to adjust the moisture content of the treated rice straw up to approximately 50%. All bags were then stored for 0 or 7 or 14 days according to treatments (0 day for untreated control; 7 days for those treatments with NaOH and 14 days for treatments with urea alone). After the appropriate storage time, duplicate samples of treated bagasse or rice straw from each bag were taken and dried in hot air oven at 60°C for 36 h. One sample from each replicate was ground through 1 mm sieve and kept for further chemical analyses. Another sample was ground through 2 mm screen and kept for nylon bag degradation study.

Samples were then analyzed for ash content (500°C overnight); crude protein (CP); ether extract (EE); crude fiber (CF), neutral detergent fiber (NDF) and acid detergent fiber (ADF) and gross energy (GE) according to the procedures described in AOAC (1990).

Four non-lactating dairy cows, ruminally cannulated, were used to study the nylon bag degradation. They were fed, at maintenance level, 6 kg DM of roughage mixed rations (10% CP, 9 MJME/kg DM), given as two equal meals per day, at 0800 and 1600 h. The rumen degradation value obtained by weighing approximately 3 g DM of individual sample into each of the nylon bags (80×110 mm; pore size 47 μm, Estal Mono, Switzerland). A total of 18 bags were suspended in the rumen of each cow prior to the morning feeding. A bag of each sample per feed per animal was incubated in the rumen for 48 h, and then removed and washed in automatic washing machine with gentle speed for 15 min., and then dried at 60°C for 36 h. After weighing each bag individually, four bags (one from each feed from each animal) of each sample were pooled to make one representative sample large enough for DM and CF determination.

All measured data were then subjected to analysis of variance (Steel and Torrie, 1986) using Statistical Analysis System (SAS, 1985) procedure of general linear model (GLM). Mean comparisons were carried out by Duncan's multiple range test.

RESULTS AND DISCUSSION

All treatment groups resulted in increased DM content of bagasse but showed reduction in DM content of rice straw (Tables 1 and 2). A reduction in DM content of rice straw can be attributed to an addition of water when NaOH and/or urea were dissolved before applying to rice straw. The crude protein (CP) contents were enhanced ($p<0.001$; 2.0-12.5 units for bagasse; 3.1-13.7 units for rice straw) by treatments containing nitrogen sources i.e. urea and the highest contents were obtained after 6% urea treatment. These increases in CP were similar to that reported for urea treated barley straw (Wanapat et al., 1985) urea plus $Ca(OH)_2$ treated rice straw (Fadel Elseed et al., 2003) but higher than that previously reported for urea treated rice straw (Wanapat et al., 1982; Jayasuriya and Pearce, 1983).

Ash contents of the treated rice straw and bagasse were increased ($p<0.001$) over the untreated control (1.5-9.7 units for bagasse; 4.2-8.8 units for rice straw). It should be noted that the ash contents of bagasse and rice straw treated with NaOH was higher than in bagasse and rice straw treated with urea. The high ash levels may have been affected by the residual NaOH. SunstØl (1984) has indicated that the high concentration of residual NaOH may limit its use. The lower gross energy (GE) values observed for the treated bagasse and rice straw were generally related to increases in ash contents.

The effects on ether extract (EE), crude fiber (CF), neutral detergent fiber (NDF) and acid detergent fiber (ADF) of the treated rice straw and bagasse were variable. However, addition of 3% NaOH with 6% urea; and 6% NaOH with 3% or 6% urea reduced CF content of rice straw and bagasse. NDF and ADF contents were reduced by NaOH treatments but not by urea treatments. The variations in results obtained in this study were similar to those obtained from treated barley straw (Wanapat et al., 1985).

The aim of chemical treatment is to increase digestibility by increasing lignin solubility or by decreasing the strength of the bonds between lignin or phenolic groups and other cell wall constituents mainly hemicellulose. Hemicelluloses are highly susceptible to extreme pH conditions (below 4 or above 8), thus increasing their solubility (Ibrahim, 1983). In case of strong alkali, NaOH saponifies uronic acid and acetic acid esters and neutralizes free uronic acid groups and thereby weakens the bonds (Fiest et al., 1970). This increases the swelling capacity of cellulose and also enables greater penetration of microbial enzymes.

Nylon bag degradability of DM and CF of bagasse were increased by treatments applying NaOH and NaOH plus urea but not urea alone. In contrast, rice straw responded significantly to both urea and NaOH as sole treatments. However, the combination of urea and NaOH did not affect the DM and CF degradability of rice straw at the inclusion rate of 3% NaOH. However, inclusion of 6% NaOH to 3 or 6% urea increased DM and CF degradability of rice straw. In contrast to the present finding, Fadel Elseed et al. (2003) found an increase in DM degradation when 2% urea plus 0.5% $Ca(OH)_2$ was applied to rice straw. Similar results were reported with ammoniated rice straw (orden et al., 2000) and with different dietary combinations of nitrogen sources, including urea and molasses, dried poultry dropping and deep stacked poultry litter, formulated with naturally fermented wheat straw (Pannu et al., 2002). This is probably due to the higher NaOH inclusion rate. Adding urea to NaOH may destroy urease activity resulted in DM and CF degradability remain unchanged at low level of NaOH but further adding NaOH, the NaOH itself caused an increase in DM and CF degradability of rice straw. Another possible reason for this is that the method of urea and NaOH treatment of bagasse by direct mixing of alkali rather than first dissolving these in water as in the case of rice straw is not appropriate since the chemical treatment may be not uniform which might have affected the results obtained with bagasse. A few researches on chemical treatment of bagasse have been published. Ibrahim (1983) reported an increase of 23 units of *in vitro* organic matter digestibility of bagasse treated with 6% NaOH, compared with an increase of 22 units of nylon bag DM degradability of bagasse treated with the same level of NaOH in the present study. However, a great response (42.2 units increase in DM digestibility) has been reported in one trial (Cabello, 1994).

The degradability values of bagasse observed were not affected by urea treatments. The lack of urease enzyme in the bagasse may contribute to the reason why treatments with urea had no effect on degradability compared with those found for urea treated rice straw. Urease enzyme found in straw led to degradation of added urea (Doyle et al., 1986). Moreover, the effect of urea alone will depend on temperature of incubation. Adding urea to NaOH may destroy urease activity as well.

From these degradability studies, it can be concluded that the most efficient treatments of bagasse were that treatment with 6% NaOH, followed by those treatments with 6% NaOH plus 3 or 6% urea and 3% NaOH plus 3 or 6% urea, respectively. While those of rice straws were treatments with 6% NaOH, followed by those treatments with 3% urea, 6% NaOH plus 6% urea, respectively. However, when comparison has been made on the cost of chemical used to treat the agricultural by-products, particularly in case of rice straw, 3-6% urea would be appropriate.

IMPLICATION

The present study clearly indicates that the most promising method to improve the nutritive value of agricultural by-products in term of increasing digestibility is to treat bagasse with 6% NaOH and to treat rice straw with 6% urea. Although the combination of NaOH and urea also improves its digestibility, but in a lesser extent, nitrogen content of bagasse or rice straw can be lifted by subsequent addition of urea. However, the relevance to the use of the methods depends on many factors, including the cost of chemicals, applicability and practicability of the method, acceptance by the farmers, and of importance the level of intake of the treated bagasse and rice straw. The clarification of these factors should be further researched.

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REFERENCES

AOAC. 1990. Official Methods of Analysis. 15th Ed. Association of Official Analytical Chemists. Virginia, USA.

Cabello, A. B. 1994. Sugar cane by-products for animal feeding: Research and development results at the Cuban Research Institute of Sugar Cane By-products (ICIDA). pp. 14-27. In: Utilization of Sugar By-products for Animal Feeding. International Society of Sugar Cane Technologists.

Doyle, P. T., C. Devendra and G. R. Pearce. 1986. Rice straw as a Feed for Ruminants. International Development Program of Australian Universities and Colleges. Canberra, Australia.

Fadel Elseed, A. M. A., J. Sekine, M. Hishinuma and K. Hamana. 2003. Effects of ammonia, urea plus calcium hydroxide and animal urine treatments on chemical composition and *in sacco* degradability of rice straw. Asian-Aust. J. Anim. Sci. 16(3):368-373.

Fiest, W. C., A. J. Baker and H. Tarkow. 1970. Alkali requirements for improving digestibility of hardwoods by rumen microorganisms. J. Anim. Sci. 30:832-835.

Ibrahim, M. N. M. 1983. Physical, chemical, physio-chemical and biological treatments of crop residues. pp. 53-68. In: The Utilization of Fibrous Agricultural Residues. Australian Government Publishing Service, Canberra.

Jayasuriya, M. C. N. and G. R. Pearce. 1983. The effect of urease enzyme on treatment time and the nutritive value of straw treated with ammonia as urea. Anim. Feed Sci. Technol. 8:271-281.

Linberg, J. E. 1985. Estimation of rumen degradability of feed proteins with the in sacco technique and various *in vitro* methods: A review. Acta Agri. Scand. (Suppl.) 25:64-97.

Orden, E. R., K. Yamaki, T. Ichinohe and T. Fujihara. 2000. Feeding value of ammoniated rice straw supplemented with rice bran in sheep. II. *In situ* rumen degradation of untreated and ammonia treated rice straw. Asian-Aust. J. Anim. Sci. 13(7):906-912.

Pannu, M. S., J. R. Kaushal, M. Wadhwa and M. P. S. Bakshi. 2002. *In sacco* degradability of dietary combinations formulated with naturally fermented wheat straw as sole roughage. Asian-Aust. J. Anim. Sci. 15(9):1307-1311.

Rangnekar, D. V. 1988. Availability and intensive utilization of sugar cane by-products. In: Non-conventional Feed Resources and Fibrous Agricultural Residues: Strategies for Expanded Utilization. International Development Research Center, Indian Council of Agricultural Research. pp. 76-93.

SAS Institute Inc. 1985. SAS User's Guide: Statistics, 5th Ed., Cary, NC.

Steel, R. D. G. and J. H. Torrie. 1986. Principles and Procedures of Statistics. A Biometrical Approach. 5th Ed. McGraw-Hill International Book Company, New York.

SunstØl, F. 1984. Ammonia treatment of straw: methods for treatment and feeding experience in Norway. Anim. Feed Sci. Technol. 10:173-187.

Wanapat, M., S. Praserdsuk, S. Chantai and A. Sivapraphagon. 1982. Effects on rice straw utilization of treatment with ammonia released from urea and/or supplementation with cassava chips. In: The Utilization of Fibrous Agricultural Residues as Animal Feeds (Ed. P. T. Doyle). University of Melbourne, Parkville, Victoria. pp. 95-101.

Wanapat, M., F. SunstØl and T. H. Garmo. 1985. Comparison of different alkali treatments applied on barley straw. In: The Utilization of Fibrous Agricultural Residues as Animal Feeds (Ed. P. T. Doyle). University of Melbourne, Parkville, Victoria. pp. 103-109.