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CHEMICAL TREATMENT OF RICE STRAW IN MALAYSIA

I. THE EFFECT ON DIGESTIBILITY OF TREATMENT WITH HIGH LEVELS OF SODIUM AND CALCIUM HYDROXIDE

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RINGKASAN

Penghadaman bahan-bahan makanan kambing biri-biri yang mengandungi 30, 40 dan 50 peratus jerami padi yang diproses dengan 6 dan 8 peratus NaOH atau $Ca(OH)_2$ didalam makanan yang mengandungi molasses dibentangkan di sini. Kandungan kimia "serabut" didalam jerami yang belum diproses dan dalam bahan kering ialah 30.4 peratus. Dengan menggunakan 6 dan 8 peratus NaOH jumlahnya telah turun kepada 29.0 dan 28.2 peratus dan dengan $Ca(OH)_2$ turun kepada 28.8 dan 28.5 peratus.

Jerami yang telah diproses dengan alkali boleh meninggikan kadar pengambilan makanan dan penghadaman bahan-bahan ($P<0.05$). Walaubagaimanapun, keputusan yang paling baik telah didapati untuk bahan makanan yang mengandungi 30 peratus jerami padi yang diproses dengan 8 peratus NaOH. Dalam perlakuan ini kadar penghadaman tiap-tiap bahan bertambah dari 60.3 ke 76.0 peratus untuk bahan kering, 35.8 ke 78.1 peratus bagi "protein kasar" 23.8 ke 67.8 peratus untuk "serabut", 34.4 ke 62.5 peratus untuk "abu" dan 34.4 ke 62.5 peratus untuk tenaga. Dengan $Ca(OH)_2$ kadar penghadaman bertambah dari 66.5 ke 73.3 peratus untuk bahan kering, 59.4 ke 68.4 peratus untuk "protein kasar", 36.4 ke 54.4 peratus untuk "serabut" dan 63.4 ke 75.8 peratus untuk tenaga. Makanan yang mengandungi 30 peratus jerami padi dan 8 peratus NaOH atau $Ca(OH)_2$ telah didapati menambahkan pengambilan tenaga ungkaibina (ME) dari1.3 kepada 1.4 MJ untuk kambing biri-biri pada tiap-tiap hari.

Perbandingan diantara alkali-alkali tersebut menunjukkan bahawa NaOH adalah lebih baik. Kadar penggunaan bergantung kepada jenis peringkat yang digunakan, cara yang digunakan dan tindakbalas yang berkesan dalam tiap-tiap percubaan makanan dan analisa kos dan keuntungan.

INTRODUCTION

The annual total production of rice straw available in Malaysia is approximately two million tonnes (DEVENDRA, 1975a), and represents an important energy source for feeding ruminants. Much of this rice straw is currently burnt *in situ*, allowed to decompose, or is used as a base for mushroom cultivation. Less than 30 per cent of the total volume produced is currently used for feeding ruminants mainly for meeting maintenance needs especially during periods of feed shortage and to satisfy bulk. There are two main reasons for this limited utilisation: firstly, limited technology due to a sparse base of knowledge, and secondly, inadequate understanding of its value as a feed. The low level of rice straw utilisation is also compounded by the fact that the by-product is poorly utilised.

Chemical treatment of cereal straws and stovers is not a new subject, and has been attempted by BECKMANN (1921) early this century. It has since then been the subject of quite considerable research in Canada (WILSON and PIGDEN, 1964; DONEFER, 1968), U.S.A. (GARRETT *et al.*, 1976), Denmark (REXEN, STIGSEN and KRISTENSEN 1975), Norway (HOMB, SUNDSTOL and ARNASON, 1976), Finland (LINKO, 1976), United Kingdom (CARMONA and GREENHALGH, 1972; JAYASURIA and OWEN, 1975; TERRY, SPOONER and OSBOURN, 1976), United Arab Republic (ABOU El HASSAN, ABOU RAYA and AL REHAB, 1971), Israel (LEVY *et al.*, 1977), India (JACKSON, 1976), Thailand (HOLM, 1972), and the Philippines (PEREZ, 1976). More recently, the alkali treatment of rice straw has been reviewed (JACKSON, 1977).

In view of the potential importance of rice straw as a source of energy for ruminants, a research programme was initiated to stimulate increased utilisation of this feed. Previous studies in this context have examined optimal level in the diet (DEVENDRA, 1975b), level of crude protein and urea as a sole source of dietary nitrogen (DEVENDRA, 1975c), the effect of carbohydrate source on the utilisation of dietary urea and nitrogen retention (DEVENDRA, 1976), and the effect of different protein sources on intake (DEVENDRA, 1977). In a continuation of this programme, and in view of the potential economic benefits associated with improving the nutritive value of straw by alkali treatment, it was appropriate to assess the effect of chemical treatment on the digestibility of rice straw in molasses-based diets. Paper one in this series presents the results of investigations on digestibility.

MATERIAL AND METHODS

Rationale for alkali treatment and use of high levels of alkali

The crude fibre content of seven rice straw varieties is about 26 to 33 per cent in the dry matter (DEVENDRA, 1975a). Lignin acts as a barrier to increased digestibility of the straw, and therefore the supply of relatively more digestible energy. Since alkali treatment disrupts the cell-wall by dissolving hemicellulose, lignin and silica by hydrolysing uronic and acetic acids esters by swelling, it is obvious that alkali treatment is beneficial. Two types and levels of alkali were used. The choice of two levels (6 and 8g per kg) was justfied on grounds of dilution with other feed ingredients in the diet (molasses, and copra cake in this case) which may render the effect of a lower level of alkali treatment less effective. Additionally, the use of low alkali levels would tend to have no effect on fibre digestibility if the level of dietary carbohydrates is high (40 per cent or more).

Treatment of rice straw

The rice straw (RS) used in the trials was of the *Bahagia* variety and was chopped to 2 7 cm lengths. The straw for the entire trial was soaked in troughs under a roof at the rate of 1 litre per kg of 6 and 8 g 100 ml solution of NaOH or $Ca(OH)_2$ overnight. Soaking was preferred to spray treatment in view of the demonstration (CARMONA and GREENHALGH, 1972) that NaOH showed better efficiency when used for soaking rather than spraying, due to better mixing. It was collected 24 hours later and stored in sacks for the duration of the trials *Table 1* presents the chemical composition of untreated and treated rice straw.

Dietary treatments

Two consecutive trials were conducted, NaOH treatment and $Ca(OH)_2$ treatment. Three levels of rice straw *(Table 2)* were used (30, 40 and 50 per cent in the diet) which were each treated with 6 and 8 g 100 ml solution of laboratory grade sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$). The 30% rice straw-molasses diet acted as control. The diets were kept iso-nitrogenous at 12 per cent crude protein with urea (feed grade) contributing about 70 per cent of the crude protein. *Table 3* and *4* gives the chemical composition of treatment diets. The diets were fed *ad libitum.*

Sheep

A total of 28 sheep in each of the two trials was used. All animals were adult rams of the indigenous sheep of Malaysia (DEVENDRA, 1975d) using the techniques for digestibility trials described previously (DEVENDRA, 1975b). They were about 3 to 4 years of age, and 16 to 20 kg in live weight. The sheep were drenched with 'Nilverm' as part of normal flock management. They were fed twice daily at 08.30 and 15.00 hours. Four sheep were used in each treatment. The sheep were rerandomised for each trial.

TABLE 1. THE CHEMICAL COMPOSITION OF UNTREATED AND TREATED RICE STRAW *(var. Bahagia)* WITH TWO TYPES OF ALKALI
(% dry matter basis)

Constituent	Untreated rice straw	+ 6 % NaOH	+ 8 % NaOH	+ 6 % $Ca(OH)_2$	+ 8 % $Ca(OH)_2$
Dry matter	91.0	90.6	90.6	92.2	91.7
Crude protein (N x 6.25)	4.2	5.8	4.9	7.4	5.6
Crude fibre	30.4	29.0	28.2	28.8	28.5
Ether extract	1.2	0.8	0.2	0.4	0.3
Ash	18.4	23.5	24.5	23.0	24.4.
Nitrogen-free extract	45.8	40.9	42.2	40.4	41.2
Gross energy (MJ/kg)	16.2	14.6	15.9	14.3	15.4

TABLE 2. COMPOSITION OF DIETS

Ingredient (% air dry basis)	Treatment 1	Treatment 2	Treatment 3
Rice straw	30.0	40.0	50.0
Molasses	41.1	31.1	21.1
Copra cake	26.0	26.0	26.0
Urea+	1.9	1.9	1.9
Mineral mixture*	1.0	1.0	1.0
Total	100.0	100.0	100.0

+Feed grade urea (280.0 per cent)

*The mineral supplement provided the following minerals and vitamins when added at the rate of 1Kg. per 100Kg : 5.000.000 IU Vitamin A; 1.250,000 IU Vitamin D; 1.3g. Cobalt; 250g. Calcium; 22.6g. Copper; 41.7g. iron; 44.2g. Manganese; 38.2g. Zinc and 113.4g. Magnesium.

Chemical analyses

50 g. samples of the daily food provided in individual treatments were bulked over seven days and subsampled for chemical analyses. A 10 per cent sample of the faeces voided was bulked (DEVENDRA and RAMLAL. 1972) thoroughly mixed. ground and subsampled for chemical analyses.

All analyses used were those recommended by A.O.A.C. (1971). and were done in duplicate. Dry matter was determined by drying at 102°C for 24 hours. ash by ashing at 600°C for 6 hours. protein by the microkjeldahl procedure. and crude fibre was determined by successive boiling with alkali and acid. Ether extract was determined by refluxing with petroleum spirit (40–60° B.P.).

TABLE 3. CHEMICAL COMPOSITION OF DIETS WITH NaOH TREATED RICE STRAW

Constituent (% DM basis)	Treatments						
	30 % RS (Control)	30 % RS + 6% NaOH	30 % RS + 8% NaOH	40 % RS + 6% NaOH	40 % RS + 8% NaOH	50 % RS + 6% NaOH	50 % RS + 8% NaOH
Dry matter	91.7	91.3	90.8	92.1	91.2	91.7	90.0
Crude protein (N x 6.25)	12.0	12.1	12.1	12.5	12.1	12.2	12.0
Crude fibre	16.7	16.4	16.2	22.5	28.7	29.4	28.6
Ether extract	1.8	1.9	1.3	1.3	1.5	1.7	1.2
Ash	14.2	14.0	16.2	16.1	16.4	17.0	18.6
Nitrogen-free extract	55.8	52.0	48.0	47.6	41.3	39.7	39.6
Gross energy (MJ/kg)	15.6	16.0	15.0	15.1	15.0	14.9	16.9

TABLE 4. CHEMICAL COMPOSITION OF DIETS WITH $Ca(OH)_2$ TREATED RICE STRAW

Constituent (% DM basis)	Treatments						
	30 % RS (Control)	30 % RS + 6% $Ca(OH)_2$	30 % RS + 8% $Ca(OH)_2$	40 % RS + 6% $Ca(OH)_2$	40 % RS + 8% $Ca(OH)_2$	50 % RS + 6% $Ca(OH)_2$	50 % RS + 8% $Ca(OH)_2$
Dry matter	98.8	98.7	98.8	98.9	98.9	91.0	94.5
Crude protein (N x 6.25)	12.2	12.2	12.2	11.9	12.1	12.1	12.2
Crude fibre	15.2	17.3	15.3	17.2	19.0	23.2	20.3
Ether extract	1.4	0.7	0.7	1.0	1.0	1.1	1.1
Ash	16.1	14.3	12.5	12.5	15.8	18.7	16.0
Nitrogen-free extract	45.1	55.5	50.1	58.3	52.1	44.9	49.2
Gross energy (MJ/kg)	14.1	14.2	15.1	15.9	15.6	17.0	17.0

Statistical analysis

The analysis of variance was carried out as described by SNEDECOR (1965), and the method of the least significant difference between means was also used.

RESULTS

Dry matter intake

The pattern of intake of dry matter due to alkali treatment using both NaOH and $Ca(OH)_2$ is shown in *Table 5*. There is no doubt that alkali treatment increased the dry matter intake. With 30 per cent rice straw + 8 per cent NaOH or $Ca(OH)_2$, the intake was increased by as much 24.2 and 26.9 per cent respectively, equivalent to intakes of 29 and 33 g. fresh rice straw per animal per day. *Table 5* also shows calculations of the intake per kg $W^{0.75}$ and as relative intake.

NaOH treatment

Table 6 summarises the effect of NaOH treatment on the digestibility of individual constituents. Statistically significant effects ($P<0.05$) were found for all constituents. The apparent digestibility coefficient of dry matter on the 30 per cent RS control diet was 60.3, whereas with NaOH treatment, the values were significantly ($P<0.05$) increased up to 76.0 per cent, an increase of 16 per cent digestibility units for the 30 per cent RS + 6 per cent alkali, and then declined. Organic matter digestibility also followed the same trend. Crude protein digestibility was significantly improved ($P<0.05$) for all diets with alkali treated rice straw.

Concerning crude fibre, NaOH treatment significantly ($P<0.05$) improved the digestibility in all treatment diets. The highest crude fibre digestibility was noted in the 40 per cent rice straw diets treated with 6 per cent NaOH, beyond which the digestibility declined. Ash digestibility was also significantly improved ($P<0.05$), for all treatments except the 50 per cent rice straw diet treated with 8 per cent NaOH. As would be expected, the digestibility of energy was also improved with NaOH for all treatments except the 50 per cent rice straw diet + 8 per cent NaOH. The highest energy digestibility was noted for the 30 per cent rice straw level treated with 8 per cent NaOH. The overall results suggest that the best response were obtained with a 30 per cent rice straw diet treated with 8 per cent NaOH.

$Ca(OH)_2$ treatment

Table 7 summarises the effect of $Ca(OH)_2$ treatment on the digestibility of individual contituents. The observation in the first trial (NaOH treatment) for the digestibility of each constituent to improve with alkali treatment was also confirmed in this trial. However, there was a tendency for the values to be generally lower. No statistically significant differences were found between treatments in dry matter, organic matter and crude protein digestibility.

Crude fibre digestibility was improved with $Ca(OH)_2$ treatment for all the 30 and 40 per cent rice straw diets, the highest digestibility was noted for the 30 per cent rice straw level + 8 per cent NaOH. Ash digestibility unlike trial one, decreased for all treatments with $Ca(OH)_2$ addition, and was significantly lower ($P<0.05$) compared to the control diet. Energy digestibility was significantly higher ($P<0.05$) for the 30 per cent rice straw + 8 per cent $Ca(OH)_2$ treatment, and significantly lower ($P<0.05$), for the 50 per cent rice straw + 6 per cent $Ca(OH)_2$ diet. The overall result which is similar to trial one suggests that the best results were obtained with a 30 per cent level of rice straw treated with 8 per cent $Ca(OH)_2$.

TABLE 5. THE INTAKE OF DRY MATTER ON INDIVIDUAL DIETS CONTAINING RICE STRAW TREATED WITH NaOH OR $Ca(OH)_2$ (g./animal/day)

Treatment	30 % RS (Control)	30 % RS + 6% alkali	30 % RS + 8% alkali	40 % RS + 6% alkali	40 % RS + 8% alkali	50 % RS + 6% alkali	50 % RS + 8% alkali
NaOH	363c*	433a*	451a*	424ab*	413b*	366c*	386c*
Relative intake**(g)	57.3	68.0	69.9	66.6	64.8	57.5	60.9
Intake/$W^{0.75}$(g)	45.8	54.4	55.8	53.2	51.9	46.0	48.7
$Ca(OH)_2$	368c*	451a	467a	459a	439ab	412ab	396c
Relative intake (g)	57.5	68.6	70.7	70.4	67.0	62.6	60.5
Intake/$W^{0.75}$ (g)	46.0	54.8	56.5	56.3	57.0	50.1	48.4

*Means on the same line with different italicised letters differ significantly ($P<0.05$)

**Relative intake $= \frac{\text{observed intake}}{80 \times kg^{0.75}}$

TABLE 6. DIGESTIBILITY COEFFICIENTS OF NaOH TREATED AND UNTREATED RICE STRAW MOLASSES DIETS (%)

(Each value is the mean of 4 sheep)

Constituent	Treatments							L.S.D.* P<0.05
	30 % RS (Control)	30 % RS + 6% NaOH	30 % RS + 8% NaOH	40 % RS + 6% NaOH	40 % RS + 8% NaOH	50 % RS + 6% NaOH	50 % RS + 8% NaOH	
Dry matter	60.3	73.3	76.0	68.9	**69.5**	68.4	60.8	7.5
Organic matter	64.6	76.8	78.6	72.1	73.0	71.7	64.7	7.3
Crude protein	35.8	77.4	78.1	70.6	66.7	70.0	66.7	10.6
Crude fibre	23.8	60.5	67.8	75.1	72.7	64.8	61.0	11.1
Ether extract	78.1	87.6	84.7	85.6	90.3	93.8	88.3	8.9
Nitrogen-free extract	78.7	82.9	83.7	59.9	69.8	78.1	78.0	11.8
Ash	34.4	51.5	62.5	52.2	51.8	52.0	43.5	12.3
Energy	63.5	75.1	76.0	68.9	68.8	67.2	59.2	7.3

*Least significant difference

TABLE 7. DIGESTIBILITY COEFFICIENTS OF $Ca(OH)_2$ TREATED AND UNTREATED RICE STRAW - MOLASSES DIETS (%)
(Each value is the mean of 4 sheep)

Constituent	Treatments							L.S.D.* $P<0.05$
	30 % RS (Control)	30 % RS + 6% $Ca(OH)_2$	30 % RS + 8% $Ca(OH)_2$	40 % RS + 6% $Ca(OH)_2$	40 % RS + 8% $Ca(OH)_2$	50 % RS + 6% $Ca(OH)_2$	50 % RS + 8% $Ca(OH)_2$	
Dry matter	66.5	72.1	73.3	65.9	64.1	48.7	59.0	7.0
Organic matter	66.4	76.6	77.9	72.1	69.7	56.1	65.5	6.1
Crude protein	59.4	63.2	68.4	43.2	69.2	50.4	64.5	9.9
Crude fibre	36.4	51.5	54.4	52.0	52.3	42.3	40.7	12.9
Ether extract	79.8	65.1	64.2	67.5	68.0	55.1	63.9	9.5
Nitrogen-free extract	76.8	86.7	85.8	81.3	76.6	65.3	76.0	7.6
Ash	66.8	45.0	41.5	22.3	34.1	16.6	25.5	14.4
Energy	63.4	68.3	74.8	68.7	66.7	57.6	66.1	7.0

*Least significant difference

Efficacy of alkali treatment

Since it was of interest to assess the efficacy of the two alkalis used, the effects on the digestibility of dry matter, organic matter and crude fibre were tested. For this purpose, Bartlett's test of homogeneity of variance was used, and no significant differences were found for the digestibility of the three constituents. This then permitted an analysis of variance calculation, which indicated that alkali treatment affected significantly dry matter digestibility ($P<0.01$), organic matter digestibility ($P<0.05$) and crude fibre digestibility ($P<0.01$.)

DISCUSSION

The effect of NaOH or $Ca(OH)_2$ treatment increased the dry matter intake significantly ($P<0.05$) compared to untreated rice straw. This result is consistent with a similar observation in alkali-treated roughage fed with other ingredients in the diet (GARRETT *et al.*, 1974; MCMANUS *et al.*, 1974) or when residual alkali was washed out (CARMONA and GREENHALGH, 1972). The increase in voluntary intake is probably due to reduced retention time in the rumen. Where either other feed ingredients are not used, or the alkali is not washed out, a reduction in intake is common (SINGH and JACKSON, 1971; HOLM, 1972; REXEN, STIGSEN and KRISTENSEN, 1975). This reduction is directly related to the amount of alkali used and also due to reduced palatability. By comparison, KISHAN, RANJHAN and NETKE (1973) found no differences in intake between treated and untreated wheat straw given to buffalo calves.

The increase in dry matter intake with alkali treatment has also been noted by CARMONA and GREENHALGH (1972) and implies that the intake and therefore supply of metabolisable energy (ME) was also increased. It was calculated that this increased intake increased the supply of 1.3 MJ and 1.4 MJ of ME per sheep per day for 30 per cent rice straw + 8 per cent NaOH or $Ca(OH)_2$. These increases (25.2 and 26.2 per cent) are significant in that the efficiency of rice straw to supply energy is considerably extended, and this is important especially in situations where rice straw supply is plentiful. The improved energy value is probably due to increased cellulolytic activity of the bacterial flora (CALVET *et al.*, 1974.)

The increased digestibility of dry matter from 60.3 to between 73.3 and 76.0 for 30 per cent rice straw + 6 or 8 per cent NaOH, in trial one, and between 72.1 and 73.3 per cent for the same level of rice straw treated with 6 or 8 per cent of $Ca(OH)_2$, and also digestibility of energy is in agreement with the results of DONEFER (1968). The present results also confirm an improved organic matter digestibility noted by CARMONA and GREENHALGH, (1972).

The digestibility of protein is interesting and merits some comment. With both alkalis, the crude protein digestibility was increased. Bearing in mind that urea accounted for about 70 per cent of the total dietary crude protein supply the implications are that a more efficient use of the urea was achieved by a faster rate of fermentation, reduced retention time in the rumen and faster rate of passage. Spray-treated straw has in fact been shown to have a faster rate of passage by BOLDUAN, VOIGT and PIATKOWSKI (1974). Also, alkali treatment increases the rate as well as extent of digestion of barley straw (REXEN and THOMSEN, 1969). Previous studies (DEVENDRA, 1975b) have already demonstrated the significance of dietary urea on the intake of rice straw, and with NaOH treatment in the present study *(Table 5)*, the improvement in crude protein digestibility of 77.4 per cent compared to 35.8 per cent for the control is noteworthy. The significance of these results is also reflected in the results of DONEFER (1968) that when treated straw was fed without urea, intake was depressed. When urea was added however, there was improvement.

The pattern of digestibility of ash was different for NaOH and $Ca(OH)_2$ treatment. With NaOH, high digestibilities, higher than the control diet, were noted, but with $Ca(OH)_2$, depressed results were found. The reason for the latter situation is probably due to an excess of Ca due to $Ca(OH)_2$ addition which with the low level of P present (0.14 per cent) caused an acute Ca : P imbalance. More particularly, it may be due to the presence in rice straw of a high potassium and oxalate content which interferes with the absorption and utilisation of calcium (SEN, RAY and TALAPATRA, 1942). Also BRUNE and BREDEHORN (1962) have observed frequent negative calcium balances on rice straw diets. The situation is critical in that a level of 0.3 per cent is required for normal growth and fertility.

The review by GUGGOLZ, KOHLER and KOPFENSTEIN (1971) concerning the factors limiting the utilisation of gross energy contained in fibrous feeds indicated that (a) lignin acts as a barrier between the carbohydrate and the digestive enzymes, (b) because cellulose is crystalline, its availability to enzyme action was slow, and (c) silica inhibits carbohydrate digestibility. Since the BECKMANN (1921) procedure of soaking the straw with dilute alkali, the process has been improved further by separating the liquor from the straw by pressure and re-cycling it into the soaking bath (HART *et al.*, 1975). However, such methods have the disadvantage of causing pollution when the lye is discharged. Accordingly, a further modification that is now being developed in Sweden and elsewhere is treatment in a closed system with less environmental effects. HOMB, SUNDSTOL and ARANSON (1976) have in this context recently described alkali treatment techniques at commercial and farm level.

The method used here did not have any polluting effects of spent lye since the rate of 1 litre per kg straw was found to be adequate, with no residual left over liquid. What is significant is that the method increased crude fibre digestibility of 30 per cent rice straw level from 23.8 per cent without alkali treatment to 67.8 with 8 per cent NaOH, and 36.4 again without alkali to 54.4 per cent with 8 per cent $Ca(OH)_2$ for the same rice straw level; both improvements were significant ($P<0.05$). CARMONA and GREENHALGH (1972) have also reported an increase in cellulose digestibility of 24 units in barley straw treated with 9 per cent NaOH. Chemical treatment has quite clearly a significant and beneficial effect on the utilisation of rice straw.

The improved digestibility of alkali treated rice straw is due to the improved digestibility of cellulose. It is due to the combined effect of lignin, silica and hemicellulose being solubilised by the alkali and improved digestibility by the sheep. The sequence of events is enhanced by the cellulose swelling when treated with alkali (WHISTEHER and TENG, 1970), and hydrolysation of the inter-molecular ester linkages between uronic acid groups of hemicellulose and cellulose (TARKOW and FEIST, 1969; FEIST, BAKER and TARKOW, 1970).

Between the two alkalis, it was quite clear that NaOH was more efficient than $Ca(OH)_2$, and was associated with much higher digestibility coefficients for all parameters measured, notably dry matter, crude protein, crude fibre, ash and energy. Also, calcium hydroxide has the disadvantage of being associated with negative calcium balances even when the calcium content was apparently adequate (NATH, SAHAI and KEHAR, 1969).

The study reported here on the value and effect of alkali treatment on rice straw represents the first of its kind in Malaysia. Quite clearly, the study is consistent with several other similar studies elsewhere which together demonstrate that there are very definite beneficial effects, especially that of making the straw more valuable, more efficient utilisation of it and increased supply of ME. One potential impact of this demonstration is increasing the value of rice straw for feeding ruminants, and more particularly increasing the present low level of ruminant production in Malaysia. This improvement also has advantages of less reliance on the use of concentrate feeds.

More studies are needed to test the efficacy of alternative types of alkali, for example NaOH flakes on nutrient digestibility, and also the concurrent effects of these on the physical treatment of the straw (heat treatment and also pelleting). Such studies, to be realistic and meaningful, will also have to be extended to practical feeding trials under field conditions and subject to cost-benefit analysis.

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SUMMARY

The digestibility by sheep of nutrients in diets containing 30, 40 and 50 per cent rice straw treated with 6 and 8 per cent NaOH or $Ca(OH)_2$ in molasses-based diet is described. The content of crude fibre of untreated rice straw in the dry matter was 30.4 per cent. With 6 and 8 per cent NaOH, the value was improved to 29.0 and 28.2 per cent, and with $Ca(OH)_2$, 28.8 and 28.5 per cent.

Treatment with alkali increased the intake and improved the digestibility of all nutrients significantly ($P<0.05$). However, the best results were found for the 30 per cent level of rice straw inclusion treated with 8 per cent NaOH. For this treatment, individual digestibilities were improved from 60.3 to 76.0 per cent for dry matter, crude protein from 35.8 to 78.1 per cent, crude fibre from 23.8 to 67.8 per cent, ash from 34.4 to 62.5 per cent and energy from 34.4 to 62.5 per cent. With $Ca(OH)_2$, the improvements in digestibility were from 66.5 to 73.3 per cent for dry matter, 59.4 to 68.4 for crude protein, 36.4 to 54.4 per cent for crude fibre, and energy from 63.4 to 74.8 per cent. It was calculated that for the 30 per cent rice straw + 8 per cent NaOH diet or $Ca(OH)_2$ diets, there was an increased intake of 1.3 to 1.4 MJ of ME per sheep per day, equivalent to an increase of 25.2 and 26.2 per cent.

A comparison of the effects of both alkalis indicated that NaOH was considerably more superior. The ultimate value of NaOH treatment will depend on type of level used, method of application, beneficial responses in feeding trials and cost-benefit analysis.

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