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IMPROVEMENT IN THE DIGESTIBILITY OF RICE STRAW BY ALKALI TREATMENT

F.H. Shah, Zia-ur-Rehman, A. Majid and A.D. Khan

PCSIR Laboratories, Ferozepur Road, Lahore 16, Pakistan

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The dry matter digestibility of rice straw increased from 33.33 to 77.07 % on treatment with 3.5 % sodium hydroxide. Ammoniation (5 % w/w) and 1.5 % calcium hydroxide treatment increased dry matter digestibility up to 55.0 % and 46.07 % respectively.

INTRODUCTION

Interest in the use of straws and other crop residues as feed for ruminants has increased in recent years since other feeds such as grains and high quality forages, have become more expensive. Many attempts have been made to improve the feed value of low quality roughages by physical [1–3] chemical [4–6] and biological treatments [7,8]. Early workers showed that the digestibility of straws could be increased by soaking in sodium hydroxide solution, but recent studies were centered on the use of sodium hydroxide solution by dry method [9]. Treatment of ground cereal straw with aqueous ammonia was reported to increase its digestibility [10].

The present work was undertaken to study the effect of various alkalies on the *in vivo* digestibility of rice straw.

MATERIALS AND METHODS

Rice straw was purchased from the local market and was ground to 100 mesh size for chemical and biological treatments.

Rice straw was treated with different concentrations of commercial sodium hydroxide (1.5 – 4.0 % w/w) and commercial calcium hydroxide (0.5 – 2.5 % w/w). The material was also treated with 5.0 % concentration of aqueous ammonia and was incubated at 55 ± 5° for 15 days in a confined system. Biodegradation of untreated and pretreated straw was carried out by semisolid fermentation technique.

Semisolid fermentation of straw was done in 10 kg capacity drums. The substrate having 2 % urea, and water to substrate ratio (v/w) 2: 1 in the drums was sterilized by passing steam for half an hour. The substrate in the drums was mechanically agitated with a spindle fitted with blades (30 rpm). The fermented Reese medium [11] (1 litre) containing 2 % glucose was used as inoculum for 4 kg of the substrate. The cultures used in these studies were *Penicillium. B. polymyxa* and *Saccharomyces cereviciae.* Analytical methods were the same as reported elsewhere [12].

Digestibility Trials. In vivo Digestibility trials were carried out on a rumen fistulated cow. The samples were infused in rumen according to the rumen techniques [13] and were taken out after 48 hours. The samples were first washed with distilled water, then with alcohol and finally with distilled water. The washed samples were dried at 100 ± 5° to constant weight.

RESULTS AND DISCUSSION

Effect of Sodium Hydroxide on in vivo *Digestibility.* The rumen digestibility of rice straw, in general improved by treatment with different concentrations of sodium hydroxide (Table 1). The maximum increase in dry matter, cellulose, minerals and organic matter digestibility at 3.5 % sodium hydroxide was 77.07, 58.69, 84.35, and 70.69 % respectively. A further increase in the amount of sodium hydroxide resulted in a decrease in the digestibility which appeared to be due to alkalosis caused by excess of unreacted alkali. These findings are in accordance with the work of other workers [14,15] who reported an improvement in digestibility of different straws by alkali treatment, but observed a decrease in digestibility beyond a certain level of sodium hydroxide. The increase in the digestibility after 3.5 % sodium hydroxide treatment appears to be due to appropriate alkali treatment which breaks the bond between lignin and structural polysaccharides, thus rendering the substrate more susceptible to the action of rumen microorganisms. Improvement in *in vitro* digestibility of crop residues after alkali treatment was reported by various workers [16].

Effect of Ammonia on in vivo *Digestibility.* Results given in Table 2 show the effect of ammoniation on *in vivo*

digestibility of rice straw. It is evident from these findings that the dry matter digestibility increased from 33.33 to 55.0 % with 5 % ammonia treatment (w/w). These results are in accordance with the work of Han and Callihan [3] who reported that the digestibility of rice straw increased to 57.5 % with 5.2 % ammonia treatment. Waiss *et al.* [10] found an increase in *in vivo* dry matter digestibility of rice straw from 42.0 to 49.0 % together with an increase in nitrogen content from 0.5 to 1.5 % after treatment with ammonium hydroxide. Improvement in the digestibility of lignocellulosic materials by ammonia treatment was observed by other workers [17].

Effect of Ammonia on Alkali Treated Rice Straw. *In vivo* digestibility of rice straw treated with sodium hydroxide followed by ammonia treatment is given in Table 2. It is clear from these results that 2.0 % sodium hydroxide treated straw after ammonia treatment (5 % w/w) showed maximum digestibility of dry matter, cellulose, minerals and organic matter. A decrease in *in vivo* digestibility of the straw was observed when the amount of sodium hydroxide, before ammoniation, was gradually increased from 2–4 % (w/w). This clearly showed that pH of the rumen was disturbed due to the presence of excess of unreacted alkali in the straw. No appreciable difference between the digestibility of ammoniated 3.5 % and 4.0 % alkali treated straw was noted which clearly shows that at higher concentration of sodium hydroxide, the pH of the rumen was disturbed which resulted in a decrease in the digestibility of rice straw.

Effect of Calcium Hydroxide on in vivo *Digestibility of Rice Straw.* Effect of calcium hydroxide treatment on the digestibility of rice straw is given in Table 3. Maximum increase in dry matter, cellulose and organic matter digestibility was 46.07; 36.88 and 52.06 % respectively, when the straw was treated with 1.5 % calcium hydroxide (w/w). However, no improvement in mineral digestibility was observed which might be due to the formation of insoluble salts of calcium. Our results are in agreement with the findings of Iwata [18] who reported 55.0 % organic matter digestibility of straw with 1.0 % lime treatment. Similarly

Table 1. Rectuleo rumen digestibility of rice straw treated with sodium hydroxide.

Treatment	Cellulose digestibility % age	Mineral digestibility % age	Organic matter digestibility % age	Dry matter digestibility % age
Rice straw as such	20.74±1.01	48.64±3.10	30.94±1.95	33.33±1.74
1.5 % Sodium hydroxide	28.47±1.03	58.01±2.63	42.32±6.11	45.33±3.22
2.0 % Sodium hydroxide	30.91±1.11	56.35±1.68	49.89±3.63	47.94±2.89
2.5 % Sodium hydroxide	47.60±2.12	59.92±1.25	58.73±0.21	60.42±2.63
3.0 % Sodium hydroxide	23.58±2.32	58.45±0.96	46.22±0.11	46.12±4.66
3.5 % Sodium hydroxide	58.69±2.11	84.35±0.88	70.69±1.0	77.07±7.73
4.0 % Sodium hydroxide	30.14±2.68	47.68±0.91	41.78±0.60	41.04±2.46

Table 2. Rectuleo rumen digestibility of rice straw treated with sodium hydroxide and ammonia.

Treatment	Cellulose digestibility % age	Mineral digestibility % age	Organic matter digestibility % age	Dry matter digestibility % age
5.0 % Ammonia	41.06±1.98	41.09±3.11	53.09±2.22	55.0 ±3.42
1.5 % NaOH + 5 % Ammonia	29.95±1.68	58.63±8.05	54.25±2.61	54.40±2.93
2.0 % NaOH + 5 % Ammonia	34.14±2.12	57.69±5.08	58.35±3.11	55.52±3.70
2.5 % NaOH + 5 % Ammonia	30.38±2.32	52.10±5.98	51.46±4.26	54.51±4.83
3.0 % NaOH + 5 % Ammonia	24.04±3.00	49.17±4.89	51.13±4.65	51.23±2.67
3.5 % NaOH + 5 % Ammonia	28.23±2.98	45.24±9.06	43.44±5.80	42.16±6.12
4.0 % NaoH + 5 % Ammonia	15.70±2.68	34.59±6.81	53.60±0.44	43.97±4.05

Negi and Kehar [19] found that cellulose digestibility of rice straw improved upto 75.0 % by calcium hydroxide treatment.

Biological Treatment of Sodium Hydroxide Treated Rice Straw. Results mentioned in Tables 4 and 5 show the digestibility of alkali treated straw after incubation with cellulolytic microorganisms. A mixed culture of *Pencillium* and *B. polymyxa* propagated on 4 % alkali treated straw, increased digestibility of cellulose, minerals and organic matter to 70.14, 73.10 and 69.10 % respectively (Table 4). The digestibility of cellulose, minerals and organic matter of 3.5 % sodium hydroxide treated and biodegraded straw was 61.75, 74.19 and 65.04 % respectively, which is less than the digestibility of 4 % alkali treated and biodegraded straw. The increase in the digestibility of cellulose, minerals and organic matter was 69.58 %, 86.19 and 84.88 % when sodium hydroxide treated straw (2.5 % w/w) was fermented with a combination of *Penicillium* and

Table 3. Rectuleo rumen digestibility of rice straw treated with calcium hydroxide.

Treatment	Cellulose digestibility % age	Mineral digestibility % age	Organic matter digestibility % age	Dry matter digestibility % age
0.5 % Calcium hydroxide	11.66±1.29	44.94±2.12	41.37±1.36	37.81±3.67
1.0 % Calcium hydroxide	22.12±1.36	48.94±1.59	46.00±1.36	40.65±2.11
1.5 % Calcium hydroxide	36.88±2.29	45.45±5.20	52.06±3.95	46.07±7.47
2.0 % Calcium hydroxide	31.63±2.68	40.59±0.91	51.10±0.43	43.60±1.99
2.5 % Calcium hydroxide	34.11±2.71	52.07±6.89	51.80±1.24	39.33±5.62

Table 4. Rectuleo rumen digestibility of rice straw biodegraded after sodium hydroxide treatment.

Treatment	Cellulose digestibility % age	Mineral digestibility % age	Organic matter digestibility % age	Dry matter digestibility % age
Penicillium + B. Polymyxa	21.82±2.98	76.37±2.22	22.13±3.61	25.71±1.69
1.5 % NaOH + *Penicillium + B. polymyxa*	52.70±2.37	64.23±3.74	55.93±4.98	60.99±6.92
2.0 % NaOH + *Penicillium + B. polymyxa*	45.43±2.02	68.18±1.92	51.35±2.85	57.33±7.12
2.5 % NaOH + *Penicillium + B. polymyxa*	49.31±2.31	65.00±1.38	47.00±2.39	50.00±5.39
3.0 % NaOH + *Penicillium + B. polymyxa*	59.39±2.68	70.88±2.31	54.38±3.22	55.78±5.66
3.5 % NaOH + *Penicillium + B. polymyxa*	61.75±2.91	74.19±2.90	65.04±2.32	65.80±2.25
4.0 % NaOH + *Penicillium + B. polymyxa*	70.14±3.02	73.10±3.10	69.10±6.42	71.17±7.73

Table 5. Rectuleo rumen digestibility of rice straw biodegraded after sodium hydroxide treatment.

Treatment	Cellulose digestibility % age	Mineral digestibility % age	Organic matter digestibility % age	Dry matter digestibility % age
Penicillium + S. cerevisiae	28.07±3.11	74.10±2.01	39.30±2.91	34.46±3.93
1.5 % NaOH + *Penicillium + S. cerevisiae*	42.69±3.9	66.66±2.71	60.15±4.0	57.23±3.05
2.0 % NaOH + *Penicillium + S. cerevisiae*	40.61±2.61	61.88±1.54	56.64±1.09	57.91±2.25
2.5 % NaOH + *Penicillium + S. cerevisiae*	69.58±1.32	86.19±2.48	64.88±7.0	68.20±9.29
3.0 % NaOH + *Penicillium + S. cerevisiae*	50.48±1.33	49.41±0.88	68.25±2.87	62.15±1.64
3.5 % NaOH + *Penicillium + S. cerevisiae*	47.58±1.28	69.62±2.58	52.93±2.32	57.13±6.07
4.0 % NaOH + *Penicillium + S. cerevisiae*	53.62±2.21	70.14±2.38	59.14±2.84	60.88±6.44

Table 6. Rectuleo rumen digestibility of rice straw biodegraded after calcium hydroxide treatment.

Treatment	Cellulose digestibility % age	Mineral digestibility % age	Organic matter digestibility % age	Dry matter digestibility % age
0.5 % $Ca(OH)_2$ + *Penicillium* + *S. cerevisiae*	27.52±2.37	53.14±2.11	46.43±0.66	44.76±3.27
1.0 % $Ca(OH)_2$ + *Penicillium* + *S. cerevisiae*	39.32±2.68	52.84±2.01	40.84±1.72	41.45±2.17
1.5 % $Ca(OH)_2$ + *Penicillium* + *S. cerevisiae*	48.35±2.45	64.40±1.98	55.73±5.53	49.76±4.57
2.0 % $Ca(OH)_2$ + *Penicillium* + *S. cerevisiae*	45.30±2.38	60.10±1.66	53.79±3.1	55.04±4.46
2.5 % $Ca(OH)_2$ + *Penicillium* + *S. cerevisiae*	41.32±1.69	55.25±1.23	48.73±2.86	47.23±2.69

S. cerevisiae (Table 5). The difference in the dry matter digestibility of the samples biodegraded after alkali treatment and only treated with alkali was negligible. These results are in agreement with the findings of Peiterson [20] who reported that cellulase is produced rapidly when *S. cereviciae* in combination with *T. viride* was grown on straw. Han [21] reported 73 % increase in crude fibre digestibility when a mixed culture of *Cellulomonas* Sp and *Alcaligenes faecalis* was grown on sodium hydroxide treated rice straw. Han and Anderson [22] found 40 % increase *in vitro* rumen digestibility of straw when pretreated rye grass was biologically degraded with cellulolytic microorganism.

Biological Treatment of Calcium Hydroxide Treated Rice Straw. Dry matter digestibility increased when a mixed culture of *Penicillium* and *S. cereviciae* was propagated on calcium hydroxide treated rice straw (Table 6). Maximum dry matter digestibility was 55.04 when 2 % calcium hydroxide treated straw was fermented with this mixed culture. The second best results were obtained with 1.5 % calcium hydroxide treated straw. Digestibility of various pretreated crop residues/by-products with cellulose degrading microbes was reported by various workers [23]

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