Pakistan J. Sci. Ind. Res., Vol. 29, No. 5, October 1986

UTILIZATION OF COTTON SEED HULLS AS ANIMAL FEED*

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(Received February 10, 1985; revised April 2, 1986)

The dry matter digestibility of cotton seed hulls increased from 15.5% to 38.8% and 29.7% on treatment with 4.0% sodium hydroxide and 5.0% potassium hydroxide respectively. Digestibility of the hulls also improved on ammoniation. Reduction in lignin contents was observed by these treatments. A two to three fold increase in non-protein nitrogen was also observed after treatment with ammonia.

INTRODUCTION

Cotton is a very important cash crop in Pakistan. A large volume of crop residues are derived from cotton plant. The most important of these residues are cotton seed hulls, cotton stocks and cotton linters; about 470,000 tonnes [1] of cotton seed hulls are produced annually most of which is used as a source of roughage for livestock. It contains a considerable amount of cellulose which can be an excellent source of energy for the ruminants but the presence of lignin and cutin reduces its digestibility. Many workers [2-6] have attempted to increase the digestibility of cellulosic waste materials by subjecting these to different treatments.

The present study was undertaken to improve the *in vivo* digestibility of cotton-seed hulls using different chemical treatments.

MATERIAL AND METHODS

Cotton seed hulls collected from Koh-i-Noor Oil Mills, Kala Shah Kaku were treated with different alkalies to increase its digestibility, as follows:

Cotton seed hulls were treated with a solution of sodium hydroxide and potassium hydroxide of different concentrations (1.0-6.0% w/w), keeping 20% moisture in the substrate.

Cotton seed hulls were also treated with a solution of calcium hydroxide of different concentrations (0.5-2.5% w/w), keeping 20% moisture in the substrate.

Untreated or alkali treated hulls were also treated with different concentrations of aqueous ammonia (1.0-5.0% w/w) and were incubated at 55 ± 5°C for 15 days in a confined system.

*These studies were conducted with financial assistance from USDA under PL-480 programme.

Nitrogen was estimated by a micro-kjeldahl method [7] using $CuSO_4 - K_2SO_4 - SeO_2$ (1:9:0.02) mixture. Dry matter and ash contents were determined according to A.O.A.C. methods. [8] Cellulose was determined by Kurschner and Hanak method [9]. Lignin contents were estimated by the procedure as described in American Society for Testing and Materials Standard Methods [10] using 72% sulphuric acid.

Digestibility trials. In vivo digestibility of the treated materials was estimated according to rumen technique [11]. A dry Sahiwal cow was rumen fistulated. The samples (in six replicates) were infused in the rumen of cow at the same time and taken out after 48 hrs. These were washed with water, followed by alcohol and finally with distilled water and then dried at 100 ± 5°C to constant weight. Results of digestibility were analysed statistically and standard deviation of each sample was also calculated according to Snedecore method [12].

RESULTS AND DISCUSSION

NaOH treatment. The rumen digestibility of cotton-seed hulls, in general was improved by treatment with different concentrations of NaOH; maximum increase in dry matter, cellulose, minerals and organic matter digestibility was observed at 4.0% NaOH treatment level (Table 1). A further increase in the concentration of NaOH resulted in a decrease in the digestibility which appeared to be due to alkalosis caused by excess of unreacted alkali. These findings are in agreement with other reports [13, 14]. Sherrod and Summers [15] reported an improvement in the digestibility of fibrous components when cotton-seed hulls were treated with sodium hydroxide.

KOH treatment. Improvement in the digestibility of cotton-seed hulls by KOH treatment is given in Table 1. Dry matter digestibility of the cotton-seed hulls generally

Table 1. *In vivo* digestibility of cotton seed hulls after treatment with different alkalies

Treatment	Percentage digestibility after 48 hrs.			
	Dry matter	Cellulose	Minerals	Organic matter
Cotton seed hulls as such	15.5 ± 1.20	18.2 ± 1.23	40.7 ± 1.05	14.6 ± 1.25
1.0 % Sodium hydroxide	19.5 ± 1.04	30.2 ± 5.77	73.6 ± 2.5	16.0 ± 1.14
2.0 % Sodium hydroxide	20.5 ± 1.52	32.3 ± 2.02	71.8 ± 3.05	19.5 ± 2.13
3.0 % Sodium hydroxide	28.5 ± 2.60	30.8 ± 3.24	78.2 ± 2.73	16.7 ± 2.92
4.0 % Sodium hydroxide	38.8± 2.87	49.4 ± 2.48	89.2 ± 3.94	26.2 ± 3.92
5.0 % Sodium hydroxide	34.0 ± 1.59	40.8 ± 0.38	78.2 ± 1.23	30.1 ± 2.43
6.0 % Sodium hydroxide	28.9 ± 3.10	30.6 ± 1.93	76.9 ± 4.03	41.1 ± 2.94
1.0 % Potassium hydroxide	19.3 ± 1.84	29.7 ± 4.35	60.3 ± 3.08	24.0 ± 1.84
2.0 % Potassium hydroxide	21.1 ± 2.88	28.5 ± 1.91	63.0 ± 4.65	23.3 ± 2.18
3.0 % Potassium hydroxide	20.2 ± 4.79	31.4 ± 4.16	72.6 ± 1.74	18.7 ± 2.26
4.0 % Potassium hydroxide	23.2 ± 1.93	28.7 ± 0.89	75.6 ± 1.74	18.4 ± 1.83
5.0 % Potassium hydroxide	29.7 ± 1.23	30.9 ± 1.87	84.3 ± 1.67	24.3 ± 0.98
6.0 % Potassium hydroxide	26.0 ± 1.11	21.7 ± 1.28	79.0 ± 1.57	23.4 ± 1.55
0.5 % Calcium hydroxide	19.3 ± 0.87	30.4 ± 2.48	36.1 ± 1.27	10.5 ± 1.78
1.0 % Calcium hydroxide	23.6 ± 2.48	29.6 ± 4.67	37.6 ± 1.38	20.7 ± 3.48
1.5 % Calcium hydroxide	29.8 ± 2.10	34.3 ± 0.83	57.2 ± 2.49	15.0 ± 0.33
2.0 % Calcium hydroxide	27.0 ± 0.75	32.4 ± 3.71	21.0 ± 0.79	18.4 ± 2.99
2.5 % Calcium hydroxide	25.4 ± 3.56	29.4 ± 2.13	27.5 ± 2.33	27.7 ± 4.03

***Average of six replicates alongwith standard deviation.**

improved at all concentrations of potassium hydroxide. Maximum increase in the dry matter, cellulose, minerals and organic matter digestibility was observed with 5.0% KOH. Digestibility of KOH treated hulls was less than the NaOH treated hulls. Improvement in the digestibility of coastal bermuda grass after KOH treatment was also observed by Spencer and Amos [16].

$Ca(OH)_2$ treatment. Effect of $Ca(OH)_2$ treatment on the digestibility of cotton-seed hulls is given in Table 1. Maximum increase in dry matter digestibility was 29.8% when the hulls were treated with 1.5% $Ca(OH)_2$. A further increase in the amount of the alkali resulted in a decrease in the digestibility of the hulls which might be due to the formation of insoluble salt of calcium in excess amount. Iwata [17] and Negi and Kehar [18] found an improvement in the digestibility of straw on $Ca(OH)_2$ treatment.

NH_4OH treatment. In-vivo digestibility of cotton-seed hulls treated with different concentrations of NH_4OH is given in Table 2. It is evident from these results that the dry matter digestibility increased from 15.5 to 27.4% with 5.0% NH_4OH treatment (w/w). Hartely and Jones [19] reported an increase in *in-vitro* digestibility of barley straw by NH_4OH treatment due to the removal of some phenolic components from plant cell walls. Moore *et al.* [20] also found an increase in the digestibility of aspen and cotton treated with NH_4OH.

Effect of NH_4OH on NaOH treated hulls. Results given in Table 3 show the effect of NH_4OH on NaOH treated cotton-seed hulls. It is clear from these results that 4.0% NaOH treated hulls after NH_4OH treatment (5.0% 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 4-6% (w/w). It might be due to alkalosis caused by excess of unreacted alkali, which inhibits the growth of rumen micro-organisms.

Effect of NH_4OH on $Ca(OH)_2$ treated hulls. In vivo digestibility of cotton seed hulls first treated with $Ca(OH)_2$ and then with NH_4OH is given in Table 3. Maximum increase in dry matter, cellulose, minerals and organic matter digestibility was 31.6, 56.2, 56.4 and 23.0% respectively when 1.5% $Ca(OH)_2$ treated hulls were treated with 5.0% NH_4OH. A decrease in *in-vivo* digestibility was noted when

Table 2. *In vivo* digestibility of cotton seed hulls after ammoniation

Treatment	Percentage digestibility after 48 hrs.			
	Dry matter	Cellulose	Minerals	Organic matter
1.0 % Ammonia	22.2 ± 1.79	45.6 ± 3.10	51.0 ± 8.13	22.4 ± 1.55
2.0 % Ammonia	25.2 ± 2.6	33.2 ± 5.42	56.6 ± 5.01	24.5 ± 2.83
3.0 % Ammonia	26.7 ± 2.51	43.9 ± 0.36	54.9 ± 4.98	29.5 ± 2.14
4.0 % Ammonia	26.4 ± 0.76	40.8 ± 1.57	51.7 ± 5.03	27.9 ± 0.64
5.0 % Ammonia	27.4 ± 2.75	37.4 ± 3.32	55.7 ± 5.02	29.0 ± 2.56

*Average of six replicates alongwith standard deviation.

Table 3. *In vivo* digestibility of alkali treated cotton seed hulls after ammoniation

Treatments	Percentage digestibility after 48 hours			
	Dry matter	Cellulose	Minerals	Organic matter
1.0 % Sodium hydroxide + 5 % ammonia	26.3 ± 2.75	33.7 ± 3.32	79.7 ± 5.02	24.8 ± 2.41
2.0 % Sodium hydroxide + 5 % ammonia	29.1 ± 1.69	34.4 ± 0.89	61.3 ± 6.20	29.0 ± 1.76
3.0 % Sodium hydroxide + 5 % ammonia	36.6 ± 0.63	41.9 ± 0.96	86.4 ± 4.93	31.5 ± 2.53
4.0 % Sodium hydroxide + 5 % ammonia	39.8 ± 4.03	35.3 ± 2.32	83.9 ± 3.90	35.0 ± 1.51
5.0 % Sodium hydroxide + 5 % ammonia	23.6 ± 1.25	27.2 ± 2.34	85.7 ± 0.76	15.8 ± 1.65
6.0 % Sodium hydroxide + 5 % ammonia	27.6 ± 1.38	41.9 ± 3.19	76.5 ± 2.0	23.9 ± 1.62
1.0 % Potassium hydroxide + 5 % ammonia	28.3 ± 1.70	26.0 ± 2.77	63.3 ± 1.44	32.3 ± 1.90
2.0 % Potassium hydroxide + 5 % ammonia	29.7 ± 1.64	25.2 ± 2.92	76.7 ± 1.76	32.8 ± 1.67
3.0 % Potassium hydroxide + 5 % ammonia	32.4 ± 1.31	31.2 ± 1.90	82.6 ± 1.34	34.5 ± 1.42
4.0 % Potassium hydroxide + 5 % ammonia	31.1 ± 0.97	27.5 ± 3.46	84.0 ± 1.31	33.3 ± 1.91
5.0 % Potassium hydroxide + 5 % ammonia	33.2 ± 1.40	37.1 ± 2.47	86.9 ± 2.43	36.9 ± 2.14
6.0 % Potassium hydroxide + 5 % ammonia	28.7 ± 1.63	29.9 ± 1.26	81.2 ± 2.09	24.5 ± 1.08
0.5 % Calcium hydroxide + 5 % ammonia	25.3 ± 3.96	44.6 ± 1.11	48.2 ± 1.31	29.4 ± 0.73
1.0 % Calcium hydroxide + 5 % ammonia	27.5 ± 1.17	46.0 ± 1.26	48.0 ± 1.37	23.2 ± 1.31
1.5 % Calcium hydroxide + 5 % ammonia	31.6 ± 1.25	56.2 ± 0.63	56.4 ± 2.64	23.0 ± 3.82
2.0 % Calcium hydroxide + 5 % ammonia	28.0 ± 1.27	49.4 ± 1.78	49.6 ± 3.44	23.0 ± 1.04
2.5 % Calcium hydroxide + 5 % ammonia	24.2 ± 1.40	49.9 ± 1.37	45.8 ± 1.74	22.9 ± 3.02

*Average of six replicates alongwith standard deviation.

the amount of $Ca(OH)_2$, before ammoniation was gradually increased from 1.5-2.5% (w/w).

Effect of NH_4OH on KOH treated hulls. Results mentioned in Table 3 show the effect of NH_4OH on KOH treated cotton seed hulls. *In-vivo* digestibility of the hulls was improved by the action of NH_4OH (5.0 % w/w) on KOH treated hulls. Maximum increase in dry matter digestibility was 33.2%. Shah *et al.* [5] reported that the digestibility of alkali treated straw was further improved by ammoniation.

Effect of alkali treatments on the chemical composition of cotton-seed hulls. The effect of NaOH on the chemical composition of cotton-seed hulls is given in Table 4. Treatment with NaOH (1.0-6.0% w/w) of hulls increased the ash contents from 2.5 to 9.5% but showed no effect on nitrogen and cellulose contents. It is also apparent from these findings that the NaOH treatment reduced the lignin content from 27.8 to 23.6%. KOH treatment also resulted in a decrease in lignin contents, but to a lesser extent than NaOH. (Table 4). Treatment with $Ca(OH)_2$ increased the ash contents to 5.9% whereas cellulose content showed irregular pattern. The lignin contents of the hulls were reduced from 27.8 to 25.3% after 2.5% $Ca(OH)_2$ treatment (Table 4). Morrison [21] found that when lignin carbohydrate complexes were subjected to alkaline conditions, lignin was decrease with the formation of low molecular weight phenolic compounds. Manus and Choung [22] also reported that lignin contents of rice straw and rice hulls decreased after alkali treatment.

The effect of NH_4OH on chemical composition of cotton seed hulls is given in Table 5. A gradual increase in the nitrogen contents (two to three fold) was observed with different concentration of ammonia (1-5.0 % w/w). A decrease in lignin contents from 27.8 to 24.6% with an increase in cellulose was also observed after ammoniation. Garrett *et al* [23] observed an increase in nitrogen and cellulose contents with a decrease in lignin after ammoniation. Han and Anderson [24] also reported an increase in nitrogen contents due to reaction of ammonia with straw components to form nitrogenous compounds. A significant

Table 4. Chemical composition of cotton seed hulls after treatment with different alkalies

Treatments	Ash %	Nitrogen %	Cellulose %	Lignin %	Dry matter %
Cotton seed hulls (as such)	2.5	1.2	42.8	27.8	86.9
1.0 % NaOH	5.6	1.3	42.5	28.0	90.3
2.0 % NaOH	5.4	1.3	42.8	25.7	90.7
3.0 % NaOH	6.2	1.3	42.6	24.2	90.8
4.0 % NaOH	7.2	1.4	42.9	24.1	91.0
5.0 % NaOH	8.2	1.3	42.8	23.8	90.8
6.0 % NaOH	9.5	1.4	42.9	23.6	90.7
1.0 % KOH	4.1	1.3	42.0	26.6	82.6
2.0 % KOH	4.2	1.3	42.7	26.5	82.9
3.0 % KOH	4.7	1.4	42.3	25.3	86.5
4.0 % KOH	6.4	1.4	42.0	24.8	86.1
5.0 % KOH	8.0	1.4	42.3	24.0	87.5
6.0 % KOH	8.4	1.4	42.9	25.5	87.7
0.5 % $Ca(OH)_2$	3.4	1.3	42.9	27.7	91.8
1.0 % $Ca(OH)_2$	3.5	1.2	42.4	25.7	91.4
1.5 % $Ca(OH)_2$	3.6	1.2	42.9	25.6	91.3
2.0 % $Ca(OH)_2$	4.1	1.3	42.7	25.4	91.1
2.5 % $Ca(OH)_2$	5.9	1.3	42.9	25.3	91.8

Average of three replicates

Table 5. Chemical composition of cotton seed hulls after ammoniation

Treatments	Ash %	Nitrogen %	Cellulose %	Lignin %	Dry matter %
1.0 % ammonia	2.7	2.0	43.6	26.4	89.9
2.0 % ammonia	2.9	2.0	43.9	26.27	90.7
3.0 % ammonia	3.5	2.1	44.2	25.5	91.0
4.0 % ammonia	3.6	3.3	44.8	24.7	89.7
5.0 % ammonia	3.6	3.3	44.9	24.6	91.3

Average of three replicates

Table 6. Chemical composition of alkali treated cotton seed hulls after ammoniation

Treatments	Ash %	Nitrogen %	Cellulose %	Lignin %	Dry matter %
1.0 % NaOH + 5.0 % NH_3	3.9	3.0	43.6	24.7	90.6
2.0 % NaOH + 5.0 % NH_3	5.0	3.5	43.8	23.3	90.4
3.0 % NaOH + 5.0 % NH_3	7.0	3.3	44.0	21.3	91.2
4.0 % NaOH + 5.0 % NH_3	7.5	2.7	45.6	21.6	91.5
5.0 % NaOH + 5.0 % NH_3	9.3	2.8	45.6	21.3	90.0
6.0 % NaOH + 5.0 % NH_3	9.7	2.5	45.7	21.9	89.4
1.0 % KOH + 5.0 % NH_3	4.3	3.2	42.5	25.8	87.6
2.0 % KOH + 5.0 % NH_3	5.4	3.1	42.7	24.3	86.5
3.0 % KOH + 5.0 % NH_3	6.7	3.4	42.0	23.7	87.2
4.0 % KOH + 5.0 % NH_3	7.7	3.3	42.9	22.3	87.0
5.0 % KOH + 5.0 % NH_3	9.3	3.5	42.7	22.4	87.2
6.0 % KOH + 5.0 % NH_3	9.4	3.4	42.6	23.4	87.6
0.5 % $Ca(OH)_2$ + 5.0 % NH_3	3.3	2.3	43.2	25.3	91.4
1.0 % $Ca(OH)_2$ + 5.0 % NH_3	4.0	2.6	43.6	25.0	91.6
1.5 % $Ca(OH)_2$ + 5.0 % NH_3	4.5	2.7	43.7	24.3	92.0
2.0 % $Ca(OH)_2$ + 5.0 % NH_3	4.6	2.9	44.1	24.1	91.5
2.5 % $Ca(OH)_2$ + 5.0 % NH_3	5.8	2.9	44.6	24.0	91.8

Average of three results.

reduction in lignin contents alongwith an increase in nitrogen was also observed when NaOH, KOH or $Ca(OH)_2$ treated hulls were subjected to NH_4OH treatment (Table 6). The decrease in lignin contents, probably created large spaces within the cellulose matrix, thus increasing the accessibility of cellulolytic enzymes into the substrate. This observation is supported by the increased digestibility of hulls after treatment with different alkalies.

Acknowledgement. Thanks are due to the Director, PCSIR Laboratories, Lahore, for providing laboratory facilities to carry out these studies.

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