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DIGESTIBILITY OF STRAWS AFTER PHYSICAL TREATMENTS

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In vivo digestibility of wheat and rice straw was improved after steam/pressure treatment. Reduction in cellulose and lignin was also observed after this treatment. Digestibility of straws was improved when the particle size was reduced from 80-100 mesh. However, the digestibility was reduced when particle size was further reduced.

Key words: Straw, Physical treatments, Digestibility.

INTRODUCTION

Utilization of straws as animal feed is limited due to presence of lignin associated with cellulose and hemicellulose. Lignin reduces the digestibility of cellulose and hemicellulose by physically protecting them against enzyme degradation in the rumen. A number of different physical and chemical treatments [1-4] had already been suggested to increase the digestibility of various cellulosic waste materials. It had been shown by Kelsey and Shafizadah [5] that the rate of enzymatic saccharification of cellulosic materials was substantially increased by wet milling. The findings of Hart *et al.* [6] revealed that the digestibility of various crop residues was significantly increased after autoclaving the substrates. Therefore, the present work was undertaken to study the effect of different physical treatments on the digestibility and the chemical composition of wheat and rice straws.

MATERIAL AND METHODS

Wheat and rice straw were purchased from the local market to carry out these studies. These materials were subjected to different physical treatments as described below:-

(1) *Fine grinding.* Wheat and rice straw were ground in a ball mill and passed through 80, 100,120 and 200 mesh sieves.

(2) *Steam/pressure treatment.* The materials having 20 % moisture were autoclaved at different pressure (15-20 lbs. per sq. inch) for different intervals of time. After the reaction time, pressure was gradually released to atmospheric pressure and then the substrate was dried at 100^{o} for 24 hours.

(3) *Dry heat treatment.* The materials were evenly spread in 1/4 inch layer in enamelled trays and exposed to various temperatures in a force draft air oven for different intervals of time and then quickly cooled and kept in bottles.

Analytical methods for the estimation of nitrogen, ash, cellulose and ligning contents were the same as reported elsewhere [7-10].

In vivo digestibility. In vivo digestibility of the treated materials was estimated in nylon bags as described by Orskove *et al.* [11]. Results of the digestibility were analyzed statistically [12].

RESULTS AND DISCUSSION

Effect of particle size on the digestibility of straws. Effect of particle size (80-200 mesh) on the *in vivo* digestibility of wheat and rice straw is given in Table 1. It is evident from these findings that the digestibility of straws was improved when the particle size was reduced from 80-100 mesh. Maximum dry matter digestibility of wheat and rice straw was 43.89 and 33.33 % respectively when the straw of 100 mesh size was infused in the rumen of cow for 48 hours. It seems that reduction in particle size provides a greater surface area for attack by the rumen microorganisms and assists access of microbes to partly modified cellulose structure thus enabling them to digest the cellulose. However, the digestibility was reduced when size of the particle was further decreased. It may be that fine pieces of the straw pass through the rumen too quickly that thus escape the action of rumen enzymes. Shah *et al.* [13] had reported an improvement in the biodegradation of wheat and rice straw by reducing the particle size. Millett *et al.* [14] observed an increase in the *in vitro* digestibility of different wood species after fine grinding in a vibratory mill.

Effect of steam/pressure treatment on the digestibility of straws. In vivo digestibility of wheat and rice straw, which passed through 100 mesh sieve was significantly improved after autoclaving the material at different pressure (15-20 labs/inch^2) for different intervals of time (15-45 min.). Maximum dry matter digestibility of wheat and rice straw was 58.40 and 42.84 % respectively when the straw having 20 % moisture was autoclaved at 15 lbs/inch^2 for 30 minutes (Table 2). Improvement in the digestibility of cellulose, minerals and organic matter was also observed with the same treatment. Digestibility of the straws was not further enhanced by increasing the pressure or time of reaction. Many workers [15-16] had also reported an improvement in the feed efficiency of various cellulosic materials due to modification in the crystal structure of cellulose after steam/pressure treatment.

Effect of dry heat treatment on the digestibility of straws. In vivo digestibility of wheat and rice straw after heating at different temperatures (100, 125 and 150°) for different intervals of time (30-60 minutes) is mentioned

Table 1. Effect of particle size on the digestibility* of wheat and rice straw.

Treatment	Wheat straw				Rice straw			
	Dry matter	Cellulose	Minerals	Organic matter	Dry matter	Cellulose	Minerals	Organic matter
80 mesh	38.84 ± 2.90	25.31 ± 1.73	41.73 ± 1.03	40.31 ± 2.31	31.44 ± 1.38	17.91 ± 2.44	44.25 ± 1.68	27.77 ± 0.75
100 mesh	43.89 ± 2.26	28.37 ± 1.09	44.35 ± 1.69	41.32 ± 2.11	33.33 ± 0.69	20.74 ± 1.01	48.54 ± 3.10	30.94 ± 1.95
120 mesh	37.68 ± 3.62	19.35 ± 1.33	35.79 ± 1.33	35.69 ± 2.33	31.59 ± 3.0	19.03 ± 1.25	46.66 ± 2.11	28.88 ± 1.29
200 mesh	36.69 ± 1.25	18.25 ± 1.11	33.26 ± 1.01	33.67 ± 1.32	25.71 ± 1.69	19.36 ± 1.11	40.09 ± 0.69	25.01 ± 1.99

*Percent digestibility after 48 hours.
All values in the table are average of six replicates along with standard deviations.

Table 2. Effect of steam/pressure treatment on the digestibility* of wheat and rice straw.

Treatment		Wheat straw				Rice straw			
Pressure (Lbs/	Time (minutes)	Dry matter	Cellulose	Minerals	Organic matter	Dry matter	Cellulose	Minerals	Organic matter
15	15	49.62 ± 2.24	33.75 ± 2.11	51.23 ± 2.69	47.77 ± 1.23	37.40 ± 2.88	25.50 ± 1.25	43.30 ± 2.33	34.40 ± 2.33
20	15	50.88 ± 1.18	32.73 ± 1.07	53.33 ± 0.98	48.69 ± 1.25	37.00 ± 1.96	24.71 ± 2.63	41.11 ± 2.31	34.71 ± 2.39
15	30	58.40 ± 1.13	39.91 ± 1.27	66.73 ± 2.32	55.23 ± 2.23	42.84 ± 2.98	30.91 ± 2.61	49.30 ± 3.38	39.33 ± 2.37
20	30	57.13 ± 1.07	34.69 ± 2.33	60.23 ± 2.32	52.33 ± 2.71	39.33 ± 5.62	29.88 ± 1.77	40.29 ± 2.33	37.77 ± 3.39
15	45	57.91 ± 2.25	36.25 ± 1.23	53.21 ± 1.39	53.78 ± 1.66	41.04 ± 2.46	28.86 ± 2.61	47.70 ± 2.73	38.73 ± 0.99
20	45	55.78 ± 2.66	33.29 ± 1.73	58.91 ± 2.67	53.23 ± 2.08	42.28 ± 2.37	26.01 ± 1.09	42.31 ± 2.36	36.77 ± 0.92

*Percent digestibility after 48 hours.
All values in the table are average of six replicates along with standard deviations.

Table 3. Effect of dry heat treatment on the digestibility* of wheat and rice straw.

Treatment		Wheat straw				Rice straw			
Temperature (0°C)	Time (minutes)	Dry matter	Cellulose	Minerals	Organic matter	Dry matter	Cellulose	Minerals	Organic matter
100	30	42.75 ± 1.29	27.37 ± 1.26	45.57 ± 1.25	40.67 ± 1.31	34.47 ± 1.13	24.60 ± 1.09	51.00 ± 1.17	29.03 ± 1.33
	60	43.61 ± 1.11	28.01 ± 1.27	47.37 ± 1.44	40.38 ± 1.47	36.66 ± 3.93	25.22 ± 3.41	53.72 ± 2.63	30.69 ± 2.71
125	30	40.63 ± 2.31	22.37 ± 1.11	39.33 ± 1.38	39.33 ± 1.22	27.79 ± 1.70	17.o9 ± 2.01	43..33 ± 1.33	24.42 ± 1.05
	60	39.01 ± 2.06	20.31 ± 1.42	38.97 ± 1.49	38.93 ± 1.61	25.71 ± 1.69	15.55 ± 2.41	41.71 ± 2.22	21.22 ± 2.72
150	30	37.75 ± 1.37	30.37 ± 1.37	38.87 ± 1.53	37.37 ± 1.38	25.51 ± 1.36	14.01 ± 1.01	40.01 ± 1.22	21.78 ± 2.09
	60	36.44 ± 1.52	20.89 ± 1.63	38.41 ± 1.63	38.41 ± 1.29	24.25 ± 1.23	14.33 ± 0.78	39.90 ± 2.09	22.25 ± 2.72

*Percent digestibility after 48 hours.
All values in the table are average of six replicates along with standard deviations.

in Table 3. Maximum dry matter digestibility of wheat and rice straw was 43.61 and 36.66 % respectively when the substrate was kept at 100° for 60 minutes. A decrease in the digestibility was observed when the samples were heated above 100°. This unusual inhibitory effect may result from drying out the fibers in such a way that they do not again readily take up moisture and thus retard panetrability of the microorganisms. These results are supported by the findings of Ghose and Kostic [17] who reported that heating alone had an inhibitory effect on the saccharification of cellulose.

Effect of treatments on the chemical composition of straws. The composition of the straws showed minor variation when the particle size was reduced from 80-200 mesh. Ash did not show a regular pattern with change in particle size of wheat straw (Table 4). No change in cellulose and lignin was observed due to reduction in particle size.

Table 4. Effect of particle size on the chemical composition* of wheat and rice straw.

Treatment	Wheat straw					Rice straw				
	Ash (%)	Nitrogen (%)	Cellulose (%)	Lignin (%)	Dry matter (%)	Ash (%)	Nitrogen (%)	Cellulose (%)	Lignin (%)	Dry matter (%)
80 mesh	10.45	0.32	39.37	0.09	88.87	17.25	0.30	36.51	6.85	82.21
100 mesh	11.53	0.32	38.39	9.07	88.49	17.29	0.32	36.47	6.75	82.73
120 mesh	10.49	0.32	37.43	9.18	88.92	17.35	0.32	36.48	6.71	82.55
200 mesh	9.56	0.32	36.04	9.11	88.50	17.28	0.31	36.55	6.83	82.12

*Average of three replicates

Table 5. Effect of steam/pressure treatment on the chemical composition* of wheat and rice straw.

Treatment		Wheat straw					Rice straw				
Pressure (Lbs/ inch^2)	Time (minutes)	Ash (%)	Nitrogen (%)	Cellulose (%)	Lignin (%)	Dry matter (%)	Ash (%)	Nitrogen (%)	Cellulose (%)	Legnin (%)	Dry matter (%)
15	15	10.44	0.33	38.66	8.11	78.25	17.21	0.32	34.61	5.67	85.52
20	15	10.67	0.32	38.99	8.05	78.45	17.27	0.33	35.32	5.12	85.27
15	30	10.25	0.33	36.25	7.75	78.11	17.19	0.33	34.21	5.41	85.32
20	30	10.37	0.33	37.67	7.96	78.83	17.11	0.34	34.33	5.24	85.26
15	45	10.52	0.32	37.92	7.94	78.81	17.25	0.33	34.01	5.39	85.22
20	45	10.49	0.32	36.85	7.89	78.79	17.29	0.33	34.11	5.25	84.67

*Average of three replicates

Table 6. Effect of dry heat treatment on the chemical composition* of wheat and rice straw.

Treatment		Wheat straw					Rice straw				
Temperature (0°C)	Time (minutes)	Ash (%)	Nitrogen (%)	Cellulose (%)	Lignin (%)	Dry matter (%)	Ash (%)	Nitrogen (%)	Cellulose (%)	Legnin (%)	Dry matter (%)
100	30	10.52	0.32	38.87	9.05	92.67	17.69	0.32	36.49	6.96	88.27
	60	10.67	0.32	38.79	9.09	92.21	17.81	0.31	36.46	6.93	88.21
125	30	11.21	0.32	37.91	8.97	95.89	17.57	0.31	36.44	6.90	88.20
	60	11.22	0.33	37.65	8.92	95.67	17.47	0.32	36.37	6.82	92.69
150	30	11.09	0.32	39.05	8.92	97.81	17.63	0.32	36.39	6.82	92.69
	60	11.27	0.32	38.79	8.73	96.75	17.59	0.31	36.32	6.79	96.81

*Average of three replicates.

Results mentioned in Table 5 show the chemical composition of wheat and rice straw after steam/pressure treatment. It is evident from these results that lignin and cellulose contents were decreased by this treatment. Reduction in lignin seems to be due to the formation of some lower molecular weight phenolic components. Reduction in cellulose might be due to production of simple carbohydrates after steam/pressure treatment. Ellis *et al.* [18] had already reported the conversion of polysaccharides into monosaccharides when cotton seed hulls were autoclaved at 121^{o} for 30 minutes.

The chemical composition of the straws did not change after heating at different temperatures (100, 125 and 150^{o}) for different intervals of time (Table 6). However, an increase in the digestibility of straw was observed which might be due to some modification in the crystalline structure of cellulose and hemicellulose.

REFERENCES

1. F. Sundstoel, Anim. Feed. Sci. Technol., **10**, 173 (1984).
2. F.H. Shah, T. Firdous and Zia-ur-Rehman, Pakistan J. Sci. Ind. Res., **26**, 328 (1983).
3. F.H. Shah and Zia-ur-Rehman, Biological Wastes, **19**(1), 63 (1987).
4. B.A. Dehority and R.R. Johnson, J. Dairy Sci., **44**, 2242 (1961).
5. R.G. Kelsey and F. Shafizadeh, Biotech. Bioengg., 22, 1025 (1980).
6. M.R. Hart, H.G. Walker, R.P. Jr Grahman, P.J. Hanni, A.H. Brown and G.O. Kohler, J. Anim. Sci., **51**, 401 (1981).
7. J. Markham, Biochem. J., **36**, 790 (1942).
8. *A.O.A.C. Official Methods of Analysis* (1970), 10th ed.
9. K. Kurschner, and A. Hanak, Determination of cellulose. Z. Untersuch Lebensum, **59**, 484 (1930).
10. B.D.E. Gaillard and H.J. Nijkamp, Neth. J. Agric. Sci., **16**, 21 (1968).
11. E.R. Orskove, F.D. Hovell and E.I. Mould, Trop. Anim. Prod., **5**, 195 (1980).
12. G.W. Snedecor, *Statistical Methods* (Ames, Iowa, Iowa State College Press, 1959).
13. F.H. Shah, A. Majid and Zia-ur-Rehman, Pakistan J. Sci. Ind. Res., **25**, 242 (1982).
14. M.A. Millett, A.J. Baker, W.C. Feist, R.W. Mellenberger and L.D. Sattar, J. Anim. Sci., **31**, 781 (1970).
15. N. Nesee, J. Wallick and J.M. Harper, Biotech. Bioengg., **19**, 323 (1977).
16. R.J. Dauke, L.B. Sherrod, E.C. Nelson and A.D. Tillman, J. Anim. Sci., **25**, 181 (1966).
17. T.K. Ghose and J.A. Kostick, Adv. Chem. Series, **95**, 415 (1969).
18. I.F. Ellis, J.W. Dunning and R.H. Fash, (To Anderson Clayton & Co.) U.S. 2,426,677 SP Sept. 2 (1947) Vide. Chem. Abst., **41**, 7752 g (1947).