甘蔗バガスの加圧・NaOH処理による化学組成・消化率におよぼす影響 : I. 処理バガスの回収量・一般化学組成について(畜産学科)

The Effects of Treatment of Bagasse with Sodium Hydroxide under Steam Pressure on Chemical Changes and Digestibility

I. Effect on Sample Recovery and Proximate Composition

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I INTRODUCTION

Large quantities of industrial or agricultural lignocellulosic materials such as woods, wood by-products, papers, grain straws, seed hulls and other plant materials including sugarcane bagasse are presently going to waste causing pollution problems.

Effective use of these materials as ruminant feeds or as themselves have several advantages : (1) Most abundant organic materials and comprise about 60% of the carbon on the earth. (2) Potential nutritive value is high with more than 80% cellulosic carbohydrates. (3) Ruminants do not compete with human for them. (4) Use of them as ruminant feeds is more productive and efficient for carbon cycle than natural decaying and other methods. (5) Eliminate environmental pollution having been caused by burning or dumping them.

Although bagasse has been widely used as fuel and for production of paper mulch, paper, charcoal and furfural and has been annually obtained approximately 104 million tons in more than 100 subtropical or tropical countries, its potential nutritive value has not been utilized effectively by ruminants because of some chemical and/or physical inhibiting mechanisms involved in the penetration of enzymes from microorganisms. Therefore, some means must be employed to destroy such barriers.

Any chemical or mechanical treatments of this material, which break down these masking factors, can contribute to the digestibility improvement of the stuff. Such processing methods are use of sodium hydroxide, ball milling, radiation, microorganisms and other chemical reagents. Although treatment of bagasse with sodium hydroxide under atmospheric pressure and temperature has

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Sci. Bull. Coll. Agr. Univ. Ryukyus, **21** : 281 ~ 303 (1974)

been reported to increase its digestibility without increased performance of animals, combination of the steam pressure with the reagent is known to raise its value more prominently as compared with the use of the reagent alone (7, 8).

The purpose of this experiment was to examine the effect of sodium hydroxide treatment of sugarcane bagasse under steam pressure on sample recovery and proximate composition. Also correlations of sample recovery with these proximate nutients were determined.

II EXPERIMENTAL PROCEEDURE

1. Experimental Design

The experimental design for this research was 3 x 3 x 3 randomized factorial design with 27 treatment combinations and 2 replications. Bagasse samples were treated with 3 levels (0, 5 or 10% on dry matter basis) of sodium hydroxide (NaOH) under 3 levels (atmospheric, 150 or 300 PSI) of pressure for 3 durations (5, 15 or 25 minutes). The design is presented in Table 1.

Table 1. Randomized factorial design

Treatment No.	Factors		
	NaOH (%)	Pressure (PSI)	Time (minutes)
1			5
2		0	15
3			25
4			5
5	0	150	15
6			25
7			5
8		300	15
9			25
10			5
11		0	15
12			25
13			5
14	5	150	15
15			25
16			5
17		300	15
18			25
19			5
20		0	15
21			25
22			5
23	10	150	15
24			25
25			5
26		300	15
27			25

2. Bagasse Material

Approximately 200 pounds of bagasse, variety 50-7290, was received from Oahu Sugar Company in August of 1971. This variety is most widely grown in Hawaii and comprises about 54% of the sugarcane in the State. The material was placed in 6 paper bags, each holding about 35 pounds. The sample was mixed well to get rid of the heat established in these bags and stored in a refrigerator to prevent fermentation and molding. Two days later, the material was mixed in each bag and about 500 grams of this was taken from the bags, mixed well again and two samples of 100 grams each were prepared for the dry matter determination as received. It was 57%. On this basis, 54 samples each weighing 175 grams (equivalent to 100 g of dry bagasse) were arranged for the various treatments.

3. Apparatus for Treatment

For the treatment of bagasse under steam pressure, a pressure reaction apparatus (Series 400-High Pressure Rocker Type), supplied by the Parr Instrument Company and commonly used for catlytic hydrogenation and dehydrogenation, was employed. The maximum capacity of this equipment for pressure and temperature was 6,000 PSI or 400 atmospheres and 350℃, respectively. A thermocouple was inserted into a hole at the bottom of the cylinder and the temperture was read on a microthermometer. Pressure was recorded on a gauge attached to the top of the cylinder.

4. Treatment of Bagasse

The samples were randomly alloted to each treatment combination. Randomization was also employed for treatment order. For the treatment combinations with no pressure (No. 1 to 3, 10 to 12, and 19 to 21), bagasse was transfered into glass container and soaked with 1,500 ml of water, 0.33% (5 g of NaOH per 100 g of dry bagasse) or 0.66% (10 g of NaOH per 100 g of dry bagasse) NaOH solution for specific period shown in Table 1. The solution was decanted off and the residue was dried in a force draft oven at 50℃ and followed by the determination of the amount of recovered sample. For the grinding of the bagasse material, a Willey mill was used and the ground samples were stored in glass bottles at 25℃ until utilized for proximate analysis.

As for the treatment combinations with pressure (No. 4 to 8, and 22 to 27), the sample was poured into the cylinder of the apparatus with 1,500 ml water, 1,500 ml of 0.33 or 0.66% NaOH solution. The material was well soaked, the cylinder was closed tightly and heated up using a variac heater. To bring pressures up to 150 and 300 PSI, approximately 40 and 50 minutes were respectively required. After establishing desired pressure, these materials were treated for the specific periods of time according to the design. Following the treatment, the cylinder was removed from the apparatus as quickly as possible and cold water was applied to bring the pressure down to zero. It took about 5 minutes. The treated material was then transfered to a container with a fine screen to discant off the solution and the residue was dried, ground and stored.

5. Proximate Analysis

Proximate nutrients such as equilibrated dry matter, crude protein, crude ether extract, crude fiber and nitrogen free extract (NFE) were determined according to the methods described by the Association of Official Agricultural Chemistry (A. O. A. C.).

Ⅲ RESULTS AND DISCUSSION

1. Effects on Sample Recovery

A large amount of dry matter was lost in the solution after pressure treatment. The differences in sample recovery due to these treatment combinations (see Table 1) indicate the differences in the degree or extent of chemical and physical changes caused by such treatments in the fiber structure of the bagasse material.

The analysis of variance of sample recovery is presented in Table 2. All three factors, NaOH, pressure and time changed ($P < .01$) the amount of the material recovered. Although each factor was significant at ($P < .01$) level, the magnitude of change caused by pressure was higher than those caused by the two other factors.

A two way interaction between NaOH and pressure was observed. The summarized effects of these two factors and interaction between them are shown in Table 3. At atmospheric pressure, sample recovery was increased ($P < .05$) when bagasse was treated with 5% or 10% NaOH. These differences, however, seem to be due to sampling error. However, some increase is probably due to trapping of NaOH by the materials. This is explained by the increased ash content in NaOH treated samples (see section on ash content). At 150 PSI, the recovery increased from 88.00% to 91.40% and then decreased to 80.50% as NaOH was increased from 0% to 5% and 10%, respectively. Also at 300 PSI, the recovery increased from 72.55% to 76.12% and 76.70% when NaOH was increased from 0% to 5% and 10%, respectively. These results suggest that NaOH at higher pressure, except 10% NaOH at 150 PSI, as compared with steam pressure alone at both levels of pressures reduce dry matter loss or decrease fiber destruction. The higher dry matter loss caused by high pressure treatment without NaOH apparently attributes to (1) the carbonization of the materials or (2) prehydrolysis characteristic of the solution. Samples treated at 150 PSI or 300 PSI without NaOH smelled of burned materials whereas the combination of pressure and NaOH did not show such characteristic. Guggolz et al. (1971) reported that treatment of rye grasses and alfalfa at 400 PSI without

Table 2. Analysis of variance for sample recovery and proximate nutrients

Source of Variance	Degree of Freedom	Sample Recovery	Dry[a] Matter Content	Crude Protein Content	Ash Content	Ether Extract	Crude Fiber Content	Nitrogen Free Extract
Replications (2)	1							
NaOH (3) S	2	64.9155**	6.1016**	1.3625**	137.6200**	6.0768**	160.0928**	425.6480**
Pressure (3) P	2	4593.2716**	6.6517**	1.0818**	1.5376*	8.8632**	551.4327**	561.4154**
Time (3) T	2	73.1238**	0.1043	0.0326	0.0120	0.6212	7.6684*	12.0855**
S × P	4	93.3822**	0.8890	0.1192	0.7872	3.2224**	44.9823**	25.1105**
S × T	4	18.9761	0.2596	0.0126	0.3241	0.2468	0.8414	1.9239
P × T	4	4.9839	0.2711	0.0045	0.6859	0.7990*	3.3319	0.5425
S × P × T	8	12.9324	0.1344	0.0179	0.5036	0.2412	4.8373	3.8670
Error	26	8.3580	1.0024	0.0184	0.3712	0.2220	2.2299	2.0108

*$P < .05$

**$P < .01$

[a]Equilibrated dry matter content

Table 3. Summarized effects of NaOH and pressure on sample recovery (%) and interaction of these factors

Pressure (PSI)	NaOH (%) 0	5	10	Mean
0	*103.97	107.47	108.63	106.69^{a}
150	88.00	91.40	80.50	86.64^{b}
300	72.55	76.12	76.70	75.12^{c}
Mean	88.17^{b}	96.66^{a}	88.62^{b}	

a, b, ……… Values with the same superscript are not significantly (P>.05) different.

* Average of 6 samples

NaOH for 40 seconds caused carbonization. Van Soest (1965) called this change "non-enzymatic" and reported that water greatly increased both rate and extent of the reaction. The same worker also demonstrated that sodium metasulfite inhibited this reaction. Sodium hydroxide at high pressure seems to have a similar inhibiting function as sodium metasulfite does. Under prehydrolysis conditions, as compared to the addition of NaOH, more hydrogen ion (H^{+}) is produced and eventually increases both rate and extent of hydrolysis. The inhibiting function of sodium hydroxide is due to the fact that its presence prevents or reduces production of hydrogen ion and consequently reduces the extent of hydrolysis.

The means of 27 combinations and comparison of them using Duncan's Multiple Range Test are presented in Table 4. Also see Appendix I. The lowest mean sample recovery (67.50%) was found in treatment with 0% NaOH at 300 PSI for 25 minutes. This was not, however, significantly different from other treatments with atmospheric pressure and 150 PSI.

Dry matter loss has been reported to be very high after treatment with 1.5% to 1.8% NaOH solution even at atmospheic pressure and temperature for 3 to 24 hours. Beckmann (1921), Godden (1920), Ferguson (1942) and Ololade et al. (1970) have reported that 9% to 26% of the dry matter in wheat straw was lost in the solution when the material was treated in this way and washing was followed. In the present study, the material was not washed with water. Even so, the result shows 9% to 33% loss when pressure was applied. When 300 PSI was used, the loss was very high ; 21% to 33%. These results indicate that water washing after treatment would increase the loss further more, though washing seems to be unnecessary in these treatments becauce the

NaOH concentration is very low ; 0.33% and 0.66%. From a nutritional stand point this high dry matter loss is very important and suggests that the amount of water should be limited to minimize the loss in the solution so that animals can use these valuable nutrients.

Table 4. Means of 27 treatment combinations for sample recovery and their cmparison

Treatment No.	NaOH	PSI	Time	*$\bar{X}$(%)	Group
10	5	0	5	109.90	a
19	0	0	25	109.70	ab
20	10	0	15	108.90	ab
21	10	0	25	107.40	ab
12	5	0	25	106.50	ab
11	5	0	15	106.10	ab
1	0	0	5	105.40	ab
3	0	0	25	104.40	ab
2	0	0	15	102.20	b
4	0	150	5	95.60	c
13	5	150	5	92.50	c
15	5	150	25	90.80	c
14	5	150	15	90.00	cd
6	0	150	25	84.30	de
5	0	150	15	84.20	de
23	10	150	15	82.30	ef
24	10	150	25	80.40	efg
16	5	300	5	79.20	efgh
22	10	150	5	78.90	efgh
25	10	300	5	78.00	fgh
26	10	300	15	76.80	fgh
7	0	300	5	75.80	fgh
27	10	300	25	75.30	gh
18	5	300	25	74.90	gh
8	0	300	15	74.40	gh
17	5	300	15	74.30	gh
9	0	300	25	67.50	h

a, b, ……… Values with the same superscript are not significantly ($P > .05$) different

*Average of 2 replications

Wilson and Pigden (1964), Koers et al. (1969), Donefer et al. (1969) and Ololade et al. (1970) pointed out the importance of the dry matter loss and proposed a dry method using more concentrated NaOH solution followed by neutralization of unreacted alkali with mineral or organic acids ; silage or acetic acid. However, Donefer et al. (1969) suggest that high salt (Na) content has an antimicrobial effect and that sodium level must not exceed the ability of the animals to adjust acid-base balance.

2. Effects on Proximate Composition

A Equilibrated Dry Matter

The analysis of variance for equilibrated dry matter content is presented in Table 2. Dry matter content after equibration was changed ($P<.01$) by sodium hydroxide and pressure, but not by time. No interaction was observed. Summarized effects of NaOH and pressure is presented in Table 5.

Table 5. Summarized effects of NaOH and pressure on equilibrated dry matter content (%)

Pressure (PSI)	NaOH (%) 0	5	10	Mean
0	*94.89	94.30	94.22	94.47[b]
150	96.67	94.91	94.79	95.45[a]
300	95.79	96.10	94.53	95.58[a]
Mean	95.78[a]	95.10[ab]	94.62[b]	

a, b, ……… Values with the same superscript are not significantly ($P>.05$) different.

* Average of 6 samples

Zero percent NaOH (95.78%) had higher ($P<.05$) dry matter than 10% NaOH (94.62%). This probably indicates that materials treated with 10% NaOH is higher in amorphous region than 0% NaOH treated materials. Five percent NaOH was not different from 10%. However, pressure increased equilibrated dry matter content which probably means the lower amorphous content. Tarkow and Feist (1968 and 1969) reported that 1% NaOH solution doubled the fiber saturation point of hardwoods. These workers conclueded that the increase in swelling capacity is due to saponification of esters of 4-0 methylglucuronic acid attached to xylan chains which act as cross-links in the natural condition, limiting the swelling. Nikitin's (1966) report confirms this statement.

Comparison of means for equilibrated dry matter content is shown in Table 6. Treatment with 5% NaOH under atmospheric pressure for 25 minutes (93.92%) had lower ($P<.05$) equilibrated dry matter content than treatments with 0% NaOH under 150 PSI for 15 minutes (96.99%) and 5 minutes (96.67%), but not different from the other treatment combinations.

Table 6. Meas of 27 treatment combinations for equilibrated dry matter content and their comparison

Treatment No.	NaOH	PSI	Time	*$\bar{X}$(%)	
5	0	150	15	96.99	a
4	0	150	5	96.67	b
17	5	300	15	96.36	c
6	0	150	25	96.32	
16	5	300	5	96.10	
9	0	300	25	96.00	
18	5	300	25	95.84	
7	0	300	5	95.82	
8	0	300	15	95.57	
2	0	0	15	95.10	
27	10	300	25	95.07	
3	0	0	25	94.99	
22	10	150	5	94.89	
24	10	150	25	94.86	
26	10	300	15	94.85	
11	5	0	15	94.71	
25	10	300	5	94.66	
14	5	150	15	94.63	
1	0	0	5	94.63	
23	10	300	15	94.62	
15	5	150	25	94.57	
13	5	150	5	94.54	
20	10	0	15	94.41	
21	10	0	25	94.29	
10	5	0	5	94.28	
19	10	0	5	93.97	
12	5	0	25	93.92	

a, b, ……… Values with the same superscript are not significantly ($P > .05$) different.

*Average of 2 replications

B Crude Protein

Analysis of variance for protein content is presented in Table 2. Crude protein content was decreased ($P < .01$) by NaOH and pressure, while the duration of treatment was not significant. No interaction was observed. The summary for effects of NaOH and pressure is given in Table 7. The value was decreaseed from 1.4% to 1.24% and 0.93% as NaOH was increased from 0% to 5% and 10%, respectively. Pressure decreased the content from 1.50% to 1.07% and then increased to 1.09% as its level was increased from atmospheric to 150 PSI and 300 PSI, respectively.

Table 7. Summarized effects of NaOH and pressure on crude protein content (%)

Pressure (PSI)	NaOH (%) 0	5	10	Mean
0	*1.66	1.46	1.39	1.50[a]
150	1.35	1.12	0.75	1.07[b]
300	1.44	1.16	0.66	1.09[b]
Mean	1.48[a]	1.24[b]	0.93[c]	

a, b, ………Values with the same superscript are not significantly (P>.05) different.

*Average of 6 samples

Godden (1920) demonstrated that protein content of straw changed from 2.34% to 1.27% and 1.20% when this material was soaked in 1.5% NaOH solution overnight and treated with steam for one hour followed by washing or no washing, respectively. Archibald (1924) treated oat hulls, rice hulls, barley hulls, cottonseed hulls and flax shives with 1.5% NaOH solution for three hours followed by washing and reported that protein content was decreased 39% (from 2.26% to 1.37%) for oat hulls, 17% (from 3.02% to 2.51%) for rice hulls, 26 % (from 4.08% to 3.03%) for cottonseed hulls and 16% (from 5.24% to 4.41%) for flax shives. Ferguson (1942) immersed chopped wheat straw in 1.5% NaOH solution for 22 hours at 10 to 15℃, using 10 times the straw weight of solution and washing the material to remove excess NaOH. He reported protein contents of 2.78% for untreated straw and 2.02% for straw pulp or treated straw. King et al. (1963) found that heat caused by pelleting decreased the protein content of Coastal Bermuda grass from 13.26% to 12.33%. However, Odell et al. (1968) and Ruliffson et al. (1956) reported that application of heat to alfalfa hay or alfalfa pellet increased protein content from 14.87% to 15.62% in case of the former workers and 17.8% to 24.2% in the latter's cases. Ruliffson et al. (1956) suggested that the increased protein content represent the transformation of nitrogen into more stable form, that is, melanoidin pigments.

The means of 27 treatment combinations for crude protein and their comparison are presented in Table 8. This table shows that treatment of bagasse with 10% NaOH under steam pressure of either 150 or 300 PSI reduced ($P < .05$) the value compared to the controls, while other treatments with 0% NaOH under steam pressure and both levels of NaOH without high pressure did not significantly change protein content.

Table 8. Means of 27 treatment combinations for protein content and their comparison

Treatment No.	NaOH	PSI	Time	* $\bar{X}$(%)	
2	0	0	15	1.86	a
3	0	0	25	1.60	a b
8	0	300	15	1.55	b
1	0	0	5	1.53	b c
11	5	0	15	1.50	b c d
19	10	0	5	1.48	b c d e
10	5	0	5	1.46	b c d e
7	0	300	5	1.45	b c d e
4	0	150	5	1.42	b c d e f
12	5	0	25	1.42	b c d e f
20	10	0	15	1.36	b c d e f g
5	0	150	15	1.35	b c d e f g
21	10	0	25	1.34	b c d e f g
9	0	300	25	1.33	b c d e f g
6	0	150	25	1.29	b c d e f g
17	5	300	15	1.22	c d e f g
18	5	300	25	1.19	d e f g
13	5	150	5	1.16	e f g
14	5	150	15	1.10	f g h
15	5	150	25	1.09	g h
16	5	300	5	1.06	g h i
23	10	150	15	0.84	h i j
22	10	150	15	0.72	i j
24	10	150	25	0.70	j
25	10	300	5	0.69	j
27	10	300	15	0.67	j
26	10	300	25	0.63	j

a, b, ... Values with the same superscript are not significantly ($P > .05$) different.

* Average of 2 replications

C Ash

Ash content was significantly changed by NaOH ($P < .01$) and pressure ($P < .05$), whereas time did not have such effect. The analysis of variance is given in Table 2. No interactions were found. Means for ash content and their comparison are shown in Table 9. When 0% NaOH was used pressure treatment did not increase the value ranging from 2.62% (No.1) to 3.45% (No.4). Ash content ranged from 4.45% to 6.12% when 5% NaOH was employed. These figures were higher (P<.05) as compared to 0% NaOH treatment including the controls. In case of the 10% NaOH level, the content ranged from 6.92% to 9.14% which were higher (P<.05) than 0% and 5% NaOH levels. These increases in ash content with increased NaOH levels seem to be mainly attributed to Na retained in the mateials, although their Na contens were not determined. Rodrigues (1972, unpublished data) has also observed similar results when he treated sugarcane tops with NaOH and prepared silage. Archibald (1924) reported that 24% to 54% of NaOH was absorbed by grain hulls when this material was soaked in 1% to 3% NaOH solution for 3 hours.

Table 9. Means of 27 treatment combinations for ash content and their comparison

Treatment No.	NaOH	PSI	Time	*X̄ (%)	
21	10	0	25	9.14	a
19	10	0	5	9.05	a b
20	10	0	15	8.94	a b
23	10	150	15	8.88	a b
27	10	300	25	8.86	a b
25	10	300	5	8.41	a b
22	10	150	5	8.19	a b c
24	10	150	25	7.73	b c
26	10	300	15	6.92	c d
11	5	0	15	6.12	d e
12	5	0	25	5.68	d e f
14	5	150	15	5.23	e f
10	5	0	5	5.02	e f
16	5	300	5	4.87	e f
17	5	300	15	4.75	f g
15	5	150	25	4.74	f g
13	5	150	5	4.65	f g
18	5	300	25	4.45	f g
4	0	150	5	3.49	g h
8	0	300	15	3.11	h
9	0	300	25	3.09	h
3	0	0	25	3.06	h
7	0	300	5	2.94	h
5	0	150	15	2.92	h
2	0	0	15	2.82	h
6	0	150	25	2.77	h
1	0	0	5	2.62	h

a, b, ... Values with the same superscript are not significantly (P>.05) different.

*Average of 2 replications

D Crude Fat

Ether extract content was chnged (P<.01) by both NaOH and pressure, while no significant change was brought about by time. The analysis of variance is presented in Table 2. The summary for the main effect of NaOH and pressure is shown in Table 10. The ether extractive was increased (P<.05) from 0.58% and 0.70% to 1.83% as pressure was increased from atmospheric and 150 PSI to 300 PSI, respectively. However, the content was decreased (P<.05) from 1.68% to 0.87% and 0.56% as NaOH level was increased from 0% to 10%, respectively. This contributes to the two way interaction (P<.01) between NaOH and pressure. Also a two way interaction (P<.01) between pressure and time was found. These interactions are presented in Table 7.

Table 10. Summarized effects of NaOH, pressure and time on ether extract (%) and interactions of NaOH × pressure, and pressure × time

	Pressure (PSI)			
	0	150	300	Mean
NaOH (%)				
0	*0.62	1.03	3.40	1.68^a
5	0.63	0.51	1.46	0.87^b
10	0.48	0.56	0.65	0.56^b
Time (minutes)				
5	0.62	0.71	1.19	0.84
15	0.54	0.71	1.93	1.06
25	0.56	0.67	2.39	1.21
Mean	0.58^b	0.70^b	1.83^a	

a, b, ... Values with the same superscript are not significantly (P>.05) different.

* Average of 6 samples

Means of 27 treatment combinations for ether extract and their comparison are supplied in Table 11. Treatment of bagasse with 0% NaOH at 300 PSI for 25 minutes (No.9, 4.32%) and 15 minutes (No. 8, 3.76%) increased (P<.05) the fat content as compared to other combinations. Treatment with 5% NaOH under

300 PSI for 25 minutes (No. 18, 2.20%) was lower (P<.05) than other combinations including controls except No.17 and 7. The other combinations were not significantly different from each other and controls.

Table 11. Means of 27 treatmeant combinations for ether extract and their comparison

Treatment No.	NaOH	PSI	Time	*$\bar{X}$ (%)	
9	0	300	25	4.32	a
8	0	300	15	3.76	a
18	5	300	25	2.20	b
7	0	300	5	2.11	b c
17	5	300	15	1.39	b c d
5	0	150	15	1.10	c d
4	0	150	5	1.03	d
6	0	150	25	0.97	d
16	5	300	5	0.79	d
10	5	0	5	0.73	d
3	0	0	25	0.66	d
25	10	300	5	0.66	d
1	0	0	5	0.65	d
27	10	300	25	0.65	d
26	10	300	15	0.64	d
11	5	0	15	0.61	d
22	10	150	5	0.58	d
23	10	150	15	0.57	d
2	0	0	15	0.56	d
12	5	0	25	0.56	d
15	5	150	25	0.54	d
24	10	150	25	0.52	d
13	5	150	5	0.51	d
19	10	0	5	0.49	d
14	5	150	15	0.48	d
21	10	0	25	0.48	d
20	10	0	15	0.46	d

a, b, ... Values with the same superscript are not significantly (P>.05) different.

* Average of 2 replications

Ferguson (1942) reported that treatment of wheat straw for 22 hours increased fat content from 1.05% to 1.13%. Archibald (1924) found treatment of grain straws and grain hulls reduced ether extract content. Ruliffson et al. (1956) studied the effects of heat on pelleted alfalfa and mentioned that ether extract content was decreased by increased heat probably due to (1) combustion or volatilization of the fats or of fatty acids, following hydrolysis or (2) oxidative polymerization of unsaturated fats to produce ether-insoluble materials. King et al. (1963) reported a decrease in fat content due to the pelleting of Coastal Bermuda grass hay. These three results are not agreeable with those reported in the present paper where ether extract content was increased with heat or pressure application. However, Odell et al. (1968), Reynolds and Lindahl (1960) observed increased fat content by heat or pressure caused by pelleting.

E Crude Fiber

Crude fiber content was increased by all three factors, NaOH ($P<.01$), pressure ($P<.01$) and time ($P<.05$). The analysis of variance is offered in Table 2. The magnitude of effect of pressure was larger than that of NaOH and time. The summarized effects of NaOH and pressure is given in Table 12.

Table 12. Summarized effects of NaOH and pressure on crude fiber content (%) and interaction between these two factors

Pressure (PSI)	NaOH (%)			Mean
	0	5	10	
0	*43.71	43.17	43.51	43.46^c
150	46.34	51.92	55.86	51.37^b
300	49.32	57.02	57.70	54.12^a
Mean	46.45^c	50.14^b	52.65^a	

a, b, ········ Values with the same superscript are not significantly ($P>.05$) different.

* Average of 6 samples

At each level of NaOH, pressure consistently increased crude fiber content, while the effect of NaOH was not so at each level of pressure. This inconsistency of NaOH contributed to the two way interaction ($P<.05$) between NaOH and pressure. This interaction is also shown in Table 8. It is interesting to note that samples treated with 5% and 10% NaOH at both levels of pressure had more crude fiber content than the treatments with 0% NaOH at 300 PSI. This result is in contrast to that of sample recovery (see Table 3). Godden (1920) reported that treatment of straw with 1.5% NaOH solution overnight followed by steam treatment for one hour increased crude fiber content from 46.51% to 66.45%. This increase is similar to that presented in the present study in which the content increased from 44% to 60% (Table 15). Archibald (1924) found that crude fiber content of seed hulls was increased by treatment with 1.5% NaOH solution. The increase ranged from 4% to 22%. Godden (1920) and Archibald (1924) attributed the increased crude biber content to removal of more soluble substances such as crude protein, ether extract and N. F. E. and that this increase in soluble substances was related to the increased dry matter loss after treatment. Ruliffson et al. (1956) demonstrated that crude fiber content of pelleted alfalfa hay was increased as the extent of spontaneous heating progressed; 25.9% for normal pellet and 49.6% for pellet with black color and pitted surface due to increased heat. The workers believe that this increase is probably accounted for (1) greater stability of cellulose, hemicellulose, pentose, etc., due to chemical changes accompaning heat treatment and/or (2) chemical inertness of melanoidins formed during heating, which would contribute to the crude fiber analysis. However, some workers such as Lindahl and Reynolds (1959), Leynolds and Lindahl (1960), King et al. (1963) and Odell et al. (1968) reported that heat or pressure of pellet preparation decreased crude fiber content. The decrease in the value of these workers' data was accompanied by increase in N.F.E. or dry matter content which is in contrast to NaOH treatments (Godden, 1920 and Archibald, 1924) where crude fiber increase was accompanied by increased loss in dry matter or N. F. E. Thus in pelleting the increase in N. F. E. seems to be due to break down of ligno-cellulose compounds.

The means for crude fiber content and their comparison are presented in Table 13. Treatment with 10% NaOH under 300 PSI for 15 minutes (No. 26, 59.83 %) showed the highest content which was not significantly different from treatments 22 (56.93%), 24 (56.84%), 25 (56.70%) and 27 (56.58%), but different from the other 22 treatment combinations including controls. Treatment with 5% NaOH with atmospheric pressure for 5 minutes showed the lowest crude fiber content although it was not different from treatments 1, 2, 3, 11, 12, 19, and 21.

Table 13. Means of 27 treatment combinations for crude fiber content and their comparison

Treatment No.	NaOH	PSI	Time	* $\bar{X}$ (%)	
26	10	300	15	59.83	a
22	10	150	5	56.93	b
24	10	150	25	56.84	
25	10	300	5	56.70	
27	10	300	25	56.58	
17	5	300	15	55.60	c
18	5	300	25	55.55	
16	5	300	5	54.90	
23	10	150	15	53.82	
15	5	150	25	52.96	d
14	5	150	15	52.61	e

13	5	150	5	50.19	f
8	0	300	15	49.48	
7	0	300	5	49.27	
9	0	300	25	49.21	
6	0	150	25	48.30	
5	0	150	15	47.34	g
20	10	0	15	44.40	h
12	5	0	25	44.11	
1	0	0	5	43.96	
2	0	0	15	43.84	
21	10	0	25	43.63	
4	0	150	5	43.37	
3	0	0	25	43.32	
11	5	0	15	43.06	
19	10	0	5	42.41	
10	5	0	5	42.33	

a, b, ……… Values with the same superscript are not significantly (P>.05) different.

* Average of 2 replications

F Nitrogen Free Extract

Nitrogen free extract was affected (P<.01) by all three factors. The analysis of variance is presented in Table 2. A two way interaction (P<.01) between NaOH and pressure was observed. The summarized effect of NaOH and pressure on N.F.E. and interaction of these two factors are shown in Table 14.

Table 14. Summarized effects of NaOH and pressure on NFE (%) and interaction of these factors

Pressure (PSI)	NaOH (%)			
	0	5	10	Mean
0	*51.27	49.24	45.65	48.72^a
150	48.27	41.48	34.61	41.46^b
300	42.81	37.39	32.96	37.74^c
Mean	47.47^a	42.70^b	37.74^c	

a, b, ……… Values with the same superscript are not significantly (P>.05) different.

* Average of 6 samples

Sodium hydroxide decreased (P<.05) N. F. E. from 47.47% to 42.70% and 37.74% as its level was changed from 0% to 5% and 10%, respectively. Pressure also decreased (P<.05) the value from 48.72% to 41.46% and 37.74% when it was raised from atomospheric to 150 and 300 PSIs.

Table 9 also presents the two way interaction. The means for N. F. E. and their comparison are given in Table 15. The lowest value was observed for the treatment with 10% NaOH under 300 PSI for 15 minutes (No.26, 32.02%) which was not significantly different from treatments 27 (33.29%), 25 (33.58%) 22 (33.63%) and 24 (34.26%). It was different (P<.05) from the rest of the combinations including controls; 3 (51.44%), 2 (51.03%) and 1 (51.34%).

Table 15. Means of 27 treatment combinations for NFE content and their comparison

Treatment No.	NaOH	PSI	Time	*$\overline{X}$(%)	
3	0	0	25	51.44	a
1	0	0	5	51.34	a
2	0	0	15	51.03	a
4	0	150	5	50.75	a
10	5	0	5	50.55	a
11	5	0	15	48.83	ab
12	5	0	25	48.34	abc
5	0	150	15	47.34	bcd
6	0	150	25	46.73	bcd
19	10	0	5	46.61	bcd
21	10	0	25	45.45	cde
20	10	0	15	44.89	def
7	0	300	5	44.30	def
13	5	150	5	43.05	efg
8	0	300	15	42.17	fg
9	0	300	25	42.11	fg
15	5	150	25	40.75	gh
14	5	150	15	40.64	gh
16	5	300	5	38.43	hi
17	5	300	15	37.09	ij
18	5	300	25	36.66	ijk
23	10	150	15	35.96	ijkl
24	10	150	25	34.26	jklm
22	10	150	5	33.63	klm
25	10	300	5	33.58	klm
27	10	300	25	33.29	lm
26	10	300	15	32.02	m

a, b, ……… Values with the same superscript are not significantly (P>.05) different.

* Average of 2 replications

G Correlations

Correlation of sample recovery with proximate nutrients are presented in Table 16. The amount of sample recovered positively correlated with protein (P<.01, r=0.5690), ash (P>.05, r=0.1077) and N. F. E. (P<.01, r=0.7380) and negatively with equilibrated dry matter content (P<.01, r=−0.5494), crude fiber (P<.01, r=−0.5632) and ether extract (P<.01, r=−0.8094). These results show that treatment of bagasse with NaOH under pressure decreased protein and N. F. E. contents with increase in crude fiber content as well as dry matter and ether extract contents. This conclusion is in agreement with those of Godden (1920) and Archibald (1924), except for ether extraction.

Table 16. Correlations between sample recovery and proximate nutrients

Correlation	Coefficient
Sample recovery x equilibrated D. M. content	r = − 0.5632 **
Sample recovery x crude protein	r = 0.5690 **
Sample recovery x ash content	r = 0.1077
Sample recovery x ether extract	r = − 0.5494 **
Sample recovery x crude fiber	r = − 0.8094 **
Sample recovery x N. F. E.	r = 0.7380 **

* P<.05
** P<.01

IV SUMMARY

Hawaiian bagasse obtained from variety 50-7209, which consists approximately 54% of sugarcane grown in the State, was employed to determine the effect of sodium hydroxide treatment of this material under steam pressure on sample recovery and proximate composition. Correlation of these two criteria was also examined. The results are briefly summarized as follows :

1. All three factors greatly affected the amount of sample recovered. In particular, pressure decreased the value about 15 and 25% for 150 and 300 PSI, respectively indicating increased destruction of bagasse fiber structure.

2. Main effects of sodium hydroxide and pressure were also greatly signif-

icant in all proximate nutrients studied. In general, amounts of crude protein and N. F. E. were reduced as pressure and concentration of NaOH increased.

3. In contrast to crude protein and N. F. E., contents of ash, crude fiber and ether extract increased as pressure and NaOH levels were raised though ether extract showed an inverse relation with the latter experimental factor.

4. Elevated ash content with increased NaOH concentration seems to be mainly attributed to Na retained in the treated bagasse.

5. Examination of the correlations between sample recovery and proximate nutrients revealed that soluble substances or those readily altered by NaOH and pressure were lost in the decanted solution and the residue or recovered bagasse material became high in crude fiber content.

ACKNOWLEDGEMENTS

The author expresses his sincere appreciation to the United State Army for the finacial support.

He is also indebted to the Department of Agricultural Engineering, Department of Food Science and Technology, Department of Animal Science and the College of Tropical Agriculture of the University of Hawaii for providing him with a research assistantship.

Sincere expression of appreciation is also conveyed to the thesis committee members (Dr. R. W. Stanley, Dr. C. C. Brooks and Dr. C. M. Campbell), staff and students of the Animal Science Department for their helpful advice and encouragement which have made the achievement of this paper.

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Appendix I. Effects of NaOH, pressure and time on sample recovery and proximate nutrients (%)**

NaOH (%)	Pressure (PSI)	Time (min.)	*** No.	Sample Recovery	*Dry Matter	Protein	Ash	Ether Extract	Crude Fiber	N. F. E.
0	0	5	1	105.4 ^{ab}	94.63 ^{abc}	1.53 ^{bc}	2.62 ^{h}	0.65 ^{d}	43.96 ^{h}	51.34 ^{a}
		15	2	102.2 ^{b}	95.10 ^{abc}	1.86 ^{a}	2.82 ^{h}	0.56 ^{d}	43.84 ^{h}	51.03 ^{a}
		25	3	104.4 ^{ab}	94.99 ^{abc}	1.60 ^{ab}	3.06 ^{h}	0.66 ^{d}	43.33 ^{h}	51.44 ^{a}
	150	5	4	95.6 ^{c}	96.67 ^{ab}	1.42 ^{bcdef}	3.49 ^{gh}	1.03 ^{d}	43.37 ^{h}	50.75 ^{a}
		15	5	84.2 ^{de}	96.99 ^{a}	1.35 ^{bcdefg}	2.92 ^{h}	1.10 ^{cd}	47.34 ^{fg}	47.34 ^{bcd}
		25	6	84.3 ^{de}	96.32 ^{abc}	1.29 ^{bcdefg}	2.77 ^{h}	0.97 ^{d}	48.30 ^{f}	46.73 ^{bcd}
	300	5	7	75.8 ^{fgh}	95.82 ^{abc}	1.45 ^{bcde}	2.94 ^{h}	2.11 ^{bc}	49.27 ^{f}	44.30 ^{def}
		15	8	74.4 ^{gh}	95.57 ^{abc}	1.55 ^{b}	3.11 ^{h}	3.76 ^{a}	49.48 ^{ef}	42.17 ^{fg}
		25	9	67.5 ^{h}	96.00 ^{abc}	1.33 ^{bcdefg}	3.09 ^{h}	4.32 ^{a}	49.21 ^{f}	42.11 ^{fg}
5	0	5	10	109.9 ^{a}	94.28 ^{bc}	1.46 ^{bcde}	5.02 ^{ef}	0.73 ^{d}	42.33 ^{h}	50.55 ^{a}
		15	11	106.1 ^{ab}	94.71 ^{abc}	1.50 ^{bcd}	6.12 ^{de}	0.61 ^{d}	43.06 ^{h}	48.83 ^{ab}
		25	12	106.5 ^{ab}	93.92 ^{c}	1.42 ^{bcdef}	5.68 ^{def}	0.55 ^{d}	44.11 ^{h}	48.34 ^{abc}
	150	5	13	93.5 ^{c}	94.54 ^{abc}	1.16 ^{efg}	4.65 ^{fg}	0.51 ^{d}	50.19 ^{def}	43.05 ^{efg}
		15	14	90.0 ^{cd}	94.63 ^{abc}	1.10 ^{fgh}	5.23 ^{ef}	0.48 ^{d}	52.61 ^{cde}	40.64 ^{gh}
		25	15	90.8 ^{c}	94.57 ^{abc}	1.09 ^{gh}	4.74 ^{fg}	0.54 ^{d}	54.96 ^{cd}	40.75 ^{gh}
	300	5	16	79.2 ^{efgh}	96.10 ^{abc}	1.06 ^{ghi}	4.87 ^{efg}	0.79 ^{d}	54.90 ^{bc}	38.43 ^{hi}
		15	17	74.3 ^{gh}	96.36 ^{abc}	1.22 ^{cdefg}	4.75 ^{fg}	1.39 ^{bcd}	55.60 ^{bc}	37.09 ^{ij}
		25	18	74.9 ^{gh}	95.84 ^{abc}	1.19 ^{defg}	4.45 ^{fg}	2.20 ^{b}	55.55 ^{bc}	36.66 ^{ijk}
10	0	5	19	109.7 ^{a}	93.97 ^{c}	1.48 ^{bcde}	9.05 ^{ab}	0.49 ^{d}	42.41 ^{h}	46.61 ^{bcd}
		15	20	108.9 ^{ab}	94.41 ^{bc}	1.36 ^{bcdefg}	8.94 ^{ab}	0.46 ^{d}	44.40 ^{gh}	44.89 ^{def}
		25	21	107.4 ^{ab}	94.29 ^{bc}	1.34 ^{bcdefg}	9.14 ^{a}	0.48 ^{d}	43.67 ^{h}	45.45 ^{cde}
	150	5	22	78.9 ^{efgh}	94.89 ^{abc}	0.72 ^{ij}	8.19 ^{abc}	0.58 ^{d}	56.93 ^{abc}	33.63 ^{klm}
		15	23	82.3 ^{ef}	94.62 ^{abc}	0.84 ^{hij}	8.88 ^{ab}	0.57 ^{d}	53.82 ^{abc}	34.96 ^{ijkl}
		25	24	80.4 ^{efg}	94.86 ^{abc}	0.70 ^{j}	7.73 ^{bc}	0.52 ^{d}	56.84 ^{abc}	33.26 ^{jklm}
	300	5	25	78.0 ^{efgh}	94.66 ^{abc}	0.69 ^{j}	8.41 ^{ab}	0.62 ^{d}	56.70 ^{ab}	33.58 ^{klm}
		15	26	76.8 ^{fgh}	98.85 ^{abc}	0.63 ^{j}	6.92 ^{cd}	0.64 ^{d}	59.83 ^{ab}	32.02 ^{m}
		25	27	75.3 ^{gh}	95.07 ^{abc}	0.67 ^{j}	8.86 ^{ab}	0.65 ^{d}	56.58 ^{ab}	33.29 ^{lm}

* Equilibrated dry matter

** Average of 2 replications

*** Treatment numbers

a, b, ……… Values with the same superscript are not significantly ($P > .05$) different

甘蔗バガスの加圧・NaOH処理による化学組成・消化率におよぼす影響

I. 処理バガスの回収量・一般化学組成について

城間定夫*

要約

ハワイで最も多く（54%）栽培されている品種，50-7290より得たバガスを材料とし，三つの要素すなわち圧力（大気圧下，150 PSI，300 PSI），NaOH濃度（乾物原料に対し，0%，5%，10%）および処理時間（5分，15分，25分）が，諸化学的変化・Vitro 的消化率への効果の一環として，バガスの回収量と乾物量，粗蛋白質，粗脂肪，粗灰分，可溶性無窒素物（NFE）などの一般成分に与える影響を調べる目的で，この実験は実施された。

その結果は大要次の通りであった。

1. 処理バガスの回収量は圧力，NaOH濃度および加圧時間により大いに左右され，特に150 PSIでは15%，又300 PSIにより25%程の減量が見られ，バガスの繊維のこの要因による破壊が大であることが明らかであった。

2. また圧力とNaOH濃度はすべての一般成分の含量に影響し，概して粗白質，粗脂肪およびNFEは圧力（粗脂肪を除いて）と濃度が増すにつれてその量を減じた。

3. 逆に粗灰分と粗繊維は圧力と濃度が増すに従い，また粗脂肪はNaOHの濃度が高まるにつれて増量した。

4. NaOHの増量に粗灰分含量の増加はこの薬品の処理によりバガス内のNaの保持量が多くなったのが原因であろうと思われた。

5. バガスの回収量と一般組成分との相関々係を検討した結果，可溶物あるいは圧力，NaOHの影響を受け易い物質が水溶液やNaOH溶液中に加圧処理により溶出して失われ，残留物すなわち処理バガスの粗繊維含量が増加したことが明らかとなった。

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