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Effect of Moisture Content and Storage Time on Sweet Corn Waste Silage Quality

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Abstract

This study was aimed to investigate the effect of moisture content in sweet corn waste and fermentation period on silage quality. Three pressure levels of 0, 0.6675 and 1.0013 N/cm^2 for 1 min were assigned to sweet corn waste obtained from the sweet corn factory. Four fermentation periods at 0, 30, 60 and 90 days were assigned on silage for the 3×4 factorial experimental design. The results showed that the level of pressure yielded different values ($p < 0.01$), for the dry matter, moisture, crude fiber, nitrogen free extract, neutral detergent fiber, acid detergent fiber, acid detergent lignin, gross energy, lactic acid, acetic acid and the butyric acid, except crude protein, fat, ash and pH content. It was found that dry matter, crude fiber, neutral detergent fiber, acid detergent fiber and gross energy increased when the level of pressure increased. The period of fermentation had a significant effect ($p < 0.01$) on chemical composition. The pH levels were high at 30 days of fermentation and decreased at longer periods up to 90 days. We concluded that sweet corn waste silage with higher dry matter content and being fermented for 30 days contained the highest nutritive values among all treatments combinations.

Keywords: Fermented period, moisture content, silage, sweet corn waste

Introduction

The roughage is very important materials in feeding of cows. The by-product from agro-industry such as sweet corn waste, pineapple-peel and pineapple-pulp have been widely used in feeding of cow in Thailand especially in the past decade [1]. However, vinasses from the ethanol processing plant was first introduced to ruminant feeding in Thailand only in the past few years [2]. The use of by-product from agro-industry could be adjusted for neutral detergent fiber (NDF) for better feed quality [3]. When applying such feed from agro-industrial by-product, high moisture content was found to be significant limiting factor to produce good quality feed.

The by-product from agro-industry was obtained from the dehydration of raw material and normally left with high moisture waste products. The raw material to be used as cows feed, such as sweet corn waste mixed with pineapple-peel, pineapple-pulp and fermented with vinasses, referred to as Partial Mixed Ration or PMR [2]. This agreed to the report that preserved roughage from agro-industry waste could be used for feeding of ruminant in dry season to maintain good production efficiency [4].

Klamem *et al*. [5] reported that dry matter content about 25 - 40 % in silage was indicated good roughage for animal feeding. It was well documented that if moisture content is greater than 75 % in silage, lower nutrition would be obtained in most roughage [6,7]. This study was aimed to investigate the effects of moisture content and fermentation period on sweet corn waste silage quality obtained from the sweet corn factory.

Materials and methods

Preparation of PMR

Initially the sweet corn waste (cob, shell and corn silk) from a factory was chopped into an optimum size of 2.5 - 5 cm long before exposing to different levels of pressure levels 0, 0.6675 and 1.0013 N/cm^2. It was pressed for 1 min and mixed with pineapple-peel, pineapple-pulp into an optimum size of 0.5 - 1.0 cm in a ratio 60:30:10 respectively. After applying pressure, the material was thoroughly mixed with 7 % vinasses by fresh weight before fermentation. Each pressure level used 150 kg sweet corn waste through pressing. Then randomly a 30 kg sample the sweet corn waste at each pressure levels was mixed with 15 kg pineapple-peel, 5 kg pineapple-pulp and 3.5 kg of vinasses for fermentation, allowing thorough mixing for 15 min before ensiling.

Samples collection and analysis

Three random samples of PMR in 3 pressure groups were fermented at 0, 30, 60 and 90 days. All samples were analyzed for percent of dry matter, moisture, crude protein, ether extract, ash, crude fiber, NFE and gross energy, using the proximate analysis method [8]. The analyses of NDF, ADF and ADL were done by the detergent method [9]. The pH level was recorded by a method outlined by Bolsen *et al*. [10], and lactic acid, acetic acid and butyric acid by steam distillation as described by Cheva-Isarakul [11].

Statistical analysis

The experiment was conducted through a 3×4 factorial experiment in a completely randomized design with 3 pressure and 4 fermented periods at 0, 30, 60 and 90 days with 3 replications for each treatment. All data were analyzed by the analysis of variance by statistical analysis [12]. Means of all treatments were compared using the GLM procedure through Duncan's multiple range test.

Results and discussion

Chemical characteristics of waste products

Chemical characteristics of sweet corn waste, pineapple-peel, pineapple-pulp and vinasses were analyzed. The results revealed that at 0 N/cm^2 the percent of dry matter, moisture, crude protein, ether extract, ash, crude fiber, NFE, NDF, ADF, ADL and pH were found to be 15.56, 84.44, 7.54, 0.93, 3.14, 32.77, 55.62, 78.98, 43.87, 7.96 and 3.28 % respectively, with a gross energy of 3,983.41 cal/g. At 0.6675 N/cm^2, the dry matter, moisture, crude protein, ether extract, ash, crude fiber, NFE, NDF, ADF, ADL and pH were 15.68, 84.32, 8.46, 0.95, 2.76, 34.07, 53.57, 78.94, 45.12, 7.02 and 3.29 % respectively, with a gross energy of 3,996.07 cal/g. We found that at 1.0013 N/cm^2 the percent of dry matter, moisture, crude protein, ether extract, ash, crude fiber, NFE, NDF, ADF, ADL and pH were found to be 21.55, 78.45, 6.61, 1.05, 2.33, 35.67, 54.34, 82.52, 44.84, 6.10 and 3.44 percent respectively, and a gross energy of 4,109.17 cal/g. (**Table 1**).

The results of the chemical component analyses of pineapple-peel showed the dry matter, moisture, crude protein, ether extract, ash, crude fiber, NFE, NDF, ADF, ADL and pH were 21.95, 78.05, 4.52, 0.47, 3.46, 27.35, 64.20, 84.60, 40.11, 6.86 and 3.45 % respectively, with a gross energy of 3,963.47 cal/g. The pineapple-pulp contained dry matter, moisture, crude protein, ether extract, ash, crude fiber, NFE, NDF, ADF, ADL and pH levels of 25.57, 74.43, 4.33, 0.39, 2.23, 31.15, 61.90, 83.65, 42.34, 6.07 and 3.49 % respectively and a gross energy of 3,971.61 cal/g (**Table 1**).

Vinasses had dry matter, moisture, crude protein, ether extract, ash and pH as 35.56, 64.44, 12.43, 0.51, 20.05 and 4.23 % respectively and a gross energy of 3,222.30 cal/g. (**Table 1**).

Table 1 Chemical composition of Sweet corn waste, Pineapple-peel, Pineapple-pulp and Vinasses used in the experiment (% DM).

Items	Corn 1	Corn 2	Corn 3	Peel	Pulp	Vinasses
Dry Matter	15.56	15.68	21.55	21.95	25.57	35.56
Moisture	84.44	84.32	78.45	78.05	74.43	64.44
Crude Protein	7.54	8.46	6.61	4.52	4.33	12.43
Ether Extract	0.93	0.95	1.05	0.47	0.39	0.51
Ash	3.14	2.76	2.33	3.46	2.23	20.05
Crude Fiber	32.77	34.07	35.67	27.35	31.15	ND
NFE	55.62	53.76	54.34	64.20	61.90	ND
NDF	78.98	78.94	82.52	84.60	83.65	ND
ADF	43.87	45.12	44.84	40.11	42.34	ND
ADL	7.96	7.02	6.10	6.86	6.07	ND
pH	3.28	3.29	3.44	3.45	3.49	4.25
Gross Energy (cal/g)	3,983.41	3,996.07	4,109.17	3,963.47	3,971.61	3,222.30

Corn 1 = pressure level at 0 N/cm^2, Corn 2 = pressure level at 0.6675 N/cm^2, Corn 3 = pressure level at 1.0013 N/cm^2.

Effect of pressure levels on silage quality

The results showed that pressure levels had a significant effect ($p < 0.01$) on the percentage of dry matter, moisture, crude fiber, NFE, NDF, ADF, ADL, gross energy, lactic acid, acetic acid and butyric acid. However, we found no significant effect on the crude protein, ether extract, ash and pH levels ($p > 0.05$) at different pressures. It was found that when increasing pressure levels, dry matter, crude fiber, NDF, ADF and gross energy increased as shown in **Table 2**.

Table 2 Least squares means and standard error of chemical composition at 3 levels pressure of silage (% DM).

Items	L1	L2	L3	SE	*P*-value
Dry Matter	16.76^c	17.91^b	20.36^a	0.21	<.0001
Moisture	83.24^a	82.09^b	79.65^c	0.24	<.0001
Crude Protein	7.37	7.34	7.53	0.13	NS
Ether Extract	0.93	0.86	0.95	0.06	NS
Ash	5.14	4.99	4.90	0.10	NS
Crude Fiber	31.24^b	32.10^a	32.81^a	0.25	0.0007
NFE	55.33^a	54.72^a	53.82^b	0.23	0.0003
NDF	71.37^b	73.22^a	72.53^a	0.29	0.0006
ADF	41.06^a	39.24^b	41.05^a	0.28	0.0001
ADL	8.25^a	5.97^b	4.64^c	0.14	<.0001
Gross Energy (cal/g)	3,976.35^c	3,999.86^b	4,005.48^a	0.64	<.0001
pH	3.78	3.77	3.82	0.02	NS
Lactic acid	3.91^b	3.97^a	3.77^c	0.02	<.0001
Acetic acid	7.99^a	7.81^{ab}	7.60^b	0.10	<.0001
Butyric acid	1.55^a	1.42^b	1.29^c	0.02	<.0001

L1 = pressure level at 0 N/cm^2, L2 = pressure level at 0.6675 N/cm^2, L3 = pressure level at 1.0013 N/cm^2.
^{a,b,c} Means within the same rows with different superscripts differ ($p < 0.01$).

Effect of fermented periods on silage quality

The fermentation period had a significant effect ($p < 0.01$) on the chemical composition of silage. At longer fermentation times the break down and released plant cells is sensitive to enzymes including hemicellulase and protease. The enzyme protease has a role in protein degradation by changing the protein composition of plants in the form of non-protein nitrogen and peptides, amino acids, amides, amines and ammonia, which is a quality of lower forage crops [13] as shown in **Table 3**.

Table 3 Least squares means and standard error of chemical composition at 4 fermentation periods (% DM).

Items	D1	D2	D3	D4	SE	P-value
Dry Matter	19.66^{a}	18.18^{b}	17.51^{b}	18.02^{b}	0.25	<.0001
Moisture	80.34^{b}	81.82^{a}	82.49^{a}	81.98^{a}	0.28	0.0001
Crude Protein	7.02^{b}	7.32^{b}	7.10^{b}	8.19^{a}	0.16	<.0001
Ether Extract	0.60^{c}	0.79^{b}	0.90^{b}	1.37^{a}	0.07	<.0001
Ash	4.48^{c}	4.97^{b}	5.18^{ab}	5.39^{a}	0.12	0.0001
Crude Fiber	28.45^{c}	31.95^{b}	32.59^{b}	35.20^{a}	0.29	<.0001
NFE	59.45^{a}	54.97^{b}	54.24^{b}	49.85^{c}	0.26	<.0001
NDF	69.64^{b}	73.46^{a}	73.50^{a}	72.87^{a}	0.33	<.0001
ADF	34.81^{d}	38.95^{c}	43.53^{b}	44.51^{a}	0.33	<.0001
ADL	4.90^{c}	5.19^{c}	6.11^{b}	8.95^{a}	0.16	<.0001
Gross Energy (cal/g)	3,974.64^{c}	3,983.96^{b}	3,969.80^{d}	4,047.18^{a}	0.74	<.0001
pH	3.72^{c}	3.91^{a}	3.81^{b}	3.72^{d}	0.02	<.0001
Lactic acid	2.53^{d}	5.06^{a}	4.83^{b}	3.10^{c}	0.02	<.0001
Acetic acid	1.18^{d}	8.67^{c}	10.99^{a}	10.37^{b}	0.11	<.0001
Butyric acid	0.34^{d}	1.44^{c}	1.77^{b}	2.12^{a}	0.02	<.0001

D1 = fermented period at 0 day, D2 = fermented period at 30 day, D3 = fermented period at 60 day, D4 = fermented period at 90 day.

^{a,b,c,d} Means within the same rows with different superscripts differ ($p < 0.01$).

Interactions of pressure level and fermentation period

When considering the interaction of pressure levels and fermented periods, we found that there was no interaction for most values ($p > 0.05$), except crude fiber, NFE, NDF, ADF, ADL, gross energy, lactic acid, acetic acid and butyric acid as shown in **Tables 4 - 5**. Yahaya *et al*. [14] reported that as the duration of fermentation increased the amount of dry matter and neutral detergent fiber decreased which agrees with our study. The ingredients used in the production of silage were obtained from a sweet corn waste by-product which contained high moisture and often caused spoilage. Also vinasses obtained from the ethanol factory had high moisture content but benefit from a higher protein percentage than the sweet corn waste. The benefit from mixing vinasse in the silage was from the remaining components of the dead cell yeast which is not harmful to animals as reported by Moreira [15] with a protein content as much as 40 %.

The quality of silage can be directly evaluated by pH level [16,17] which is affected by fermentation period and usually must be less than 5 [18]. Good quality silage was found to maintain good acidic pH between 3.8 to 5 and preserved quality well [19]. When the pH was controlled between 4 to 4.2 fungus and yeast would stop growing [20,21] and maintain silage quality. If ingredients used in making silage contain high moisture, the acidic stage will be reached slowly and cause high damage and low quality silage [4,22].

Good quality silage is characterized by having lactic acid between 3 to 13 % [19,20]. The percentage of water soluble carbohydrate found in the silage together with the high sugar content allows it to undergo anaerobic fermentation process by *Lactobacilli* and *Streptococci* bacteria [23]. Good fermentation processes would yield acetic acid between 4 - 6 % [24] and butyric acid less than 0.2 % [23] which shows the operation of enterobacteria to convert sugar into acetic acid. This usually occurs in the early stages of fermentation. The clostidiabacteria will degrade lactic acid to produce butyric acid [18] if the oxygen is not fully utilized and a higher amount of acetic acid and butyric acid will be obtained, resulting in a lower quality silage [25]. If the silage contains more than 75 % moisture the palatability will be affected [26,27]. Good standard quality silage should contain 60 - 75 % moisture and no excessive water seepage [5,7]. Our study revealed 80 % moisture content in the silage which is still under standard quality. If sweet corn waste silage is to be used in making silage, we recommend putting bagasse or other ingredients to absorb moisture and increase the dry matter content for a better silage quality.

Table 4 Least squares means and standard error of chemical composition at 3 pressure levels and 4 fermentation periods (% DM).

Pressure levels (N/cm^2)	Fermented periods (Day)	DM	MT	CP	EE	Ash	CF	NFE
0	0	17.86 ± 0.45	82.14 ± 0.43	7.02 ± 0.37	0.69 ± 0.16	4.49 ± 0.25	26.18 ± 0.58	61.62 ± 0.36
	30	16.09 ± 0.41	83.91 ± 0.49	7.13 ± 0.10	0.89 ± 0.05	5.16 ± 0.20	31.39 ± 0.19	55.43 ± 0.49
	60	16.01 ± 0.07	83.99 ± 0.66	6.82 ± 0.24	0.83 ± 0.08	5.27 ± 0.14	32.94 ± 0.07	54.14 ± 0.10
	90	17.09 ± 0.11	82.91 ± 0.66	8.49 ± 0.25	1.32 ± 0.11	5.62 ± 0.20	34.43 ± 1.17	50.14 ± 0.71
0.6675	0	19.12 ± 0.55	80.88 ± 0.46	6.97 ± 0.24	0.59 ± 0.10	4.47 ± 0.18	29.03 ± 0.34	58.94 ± 0.55
	30	17.78 ± 0.54	82.22 ± 0.52	7.26 ± 0.12	0.64 ± 0.04	4.86 ± 0.15	31.81 ± 0.26	55.43 ± 0.57
	60	16.94 ± 0.27	83.06 ± 0.31	7.18 ± 0.21	0.84 ± 0.08	5.20 ± 0.06	32.23 ± 0.12	54.55 ± 0.45
	90	17.81 ± 0.31	82.19 ± 0.16	7.93 ± 0.18	1.37 ± 0.10	5.41 ± 0.36	35.32 ± 0.50	49.97 ± 0.27
1.0013	0	21.99 ± 0.51	78.01 ± 0.23	7.07 ± 0.18	0.52 ± 0.12	4.48 ± 0.22	30.15 ± 0.37	57.78 ± 0.34
	30	20.68 ± 0.57	79.32 ± 0.54	7.57 ± 0.21	0.85 ± 0.05	4.90 ± 0.11	32.64 ± 0.44	54.04 ± 0.41
	60	19.58 ± 0.36	80.42 ± 0.36	7.30 ± 0.17	1.02 ± 0.19	5.07 ± 0.02	32.59 ± 0.22	54.02 ± 0.09
	90	19.17 ± 0.58	80.83 ± 0.69	8.16 ± 0.59	1.41 ± 0.16	5.14 ± 0.32	35.85 ± 0.67	49.44 ± 0.60
Pressure levels		<.0001	<.0001	0.5671	0.4980	0.2789	0.0007	0.0003
Fermented period		<.0001	0.0001	<.0001	<.0001	0.0001	<.0001	<.0001
Interaction		0.1601	0.2792	0.6432	0.5937	0.9364	0.0102	0.0066

DM = Dry Matter, MT = Moisture, CP = Crude Protein, EE = Ether Extract, Ash = Ash, CF = Crude Fiber, NFE = Nitrogen Free Extract.

Table 5 Least squares means and standard error of chemical composition at 3 levels pressure and 4 fermentation periods (% DM).

Pressure levels (N/cm^2)	Fermented periods (Day)	NDF	ADF	ADL	GE	pH	Lactic acid	Acetic acid	Butyric acid
0	0	65.08 ± 0.23	35.97 ± 0.36	6.45 ± 0.28	3,941.62 ± 0.32	3.67 ± 0.03	2.76 ± 0.06	1.32 ± 0.06	0.46 ± 0.06
	30	72.84 ± 0.58	38.78 ± 0.12	5.95 ± 0.15	3,960.58 ± 1.68	3.92 ± 0.03	5.14 ± 0.01	9.55 ± 0.07	1.63 ± 0.03
	60	74.54 ± 0.33	45.93 ± 0.72	7.18 ± 0.55	3,953.44 ± 1.21	3.85 ± 0.02	4.40 ± 0.03	10.49 ± 0.05	1.70 ± 0.01
	90	73.00 ± 0.97	43.55 ± 0.73	13.40 ± 0.31	4,049.76 ± 2.40	3.67 ± 0.04	3.34 ± 0.01	10.61 ± 0.34	2.39 ± 0.04
0.6675	0	71.99 ± 0.26	34.38 ± 0.17	3.97 ± 0.23	4,005.70 ± 1.18	3.70 ± 0.01	2.64 ± 0.05	1.19 ± 0.01	0.39 ± 0.05
	30	74.24 ± 0.68	38.96 ± 0.15	5.94 ± 0.15	3,975.17 ± 0.67	3.92 ± 0.03	4.96 ± 0.01	8.52 ± 0.05	1.31 ± 0.02
	60	72.81 ± 1.19	39.32 ± 0.70	6.25 ± 0.14	3,957.86 ± 1.42	3.78 ± 0.01	5.25 ± 0.02	11.24 ± 0.55	1.88 ± 0.06
	90	73.82 ± 0.46	44.31 ± 1.04	7.72 ± 0.16	4,060.69 ± 1.60	3.70 ± 0.02	3.02 ± 0.01	10.29 ± 0.06	2.08 ± 0.02
1.0013	0	71.86 ± 0.40	34.08 ± 0.06	4.27 ± 0.17	3,976.61 ± 0.36	3.78 ± 0.08	2.20 ± 0.07	1.03 ± 0.02	0.18 ± 0.02
	30	73.29 ± 0.19	39.10 ± 0.68	3.67 ± 0.42	4,016.14 ± 1.06	3.90 ± 0.03	5.09 ± 0.04	7.93 ± 0.07	1.37 ± 0.03
	60	73.15 ± 0.46	45.34 ± 0.34	4.89 ± 0.12	3,998.11 ± 1.15	3.80 ± 0.03	4.83 ± 0.03	11.23 ± 0.14	1.74 ± 0.02
	90	71.80 ± 0.13	45.68 ± 0.65	5.74 ± 0.30	4,031.07 ± 0.55	3.78 ± 0.06	2.95 ± 0.03	10.20 ± 0.12	1.88 ± 0.06
Pressure levels		0.0006	0.0001	<.0001	<.0001	0.2386	<.0001	0.0320	<.0001
Fermented period		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Interaction		<.0001	<.0001	<.0001	<.0001	0.2244	<.0001	0.0003	<.0001

NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber, ADL = Acid Detergent Lignin, GE = Gross Energy.

Conclusions

Our study revealed that when increasing the level of pressure, the chemical composition in the silage would increase, except moisture, NFE, ADL lactic acid, acetic acid and butyric acid. Fermentation period has a significant effect on silage quality and showed no interaction with different pressure levels. The optimum fermentation period found in our study was found to be 30 days before feeding to ruminants and would yield silage of the most favorable quality.

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