Silage from Agricultural By-products in Thailand: Processing and Storage

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ABSTRACT : Processing and storage of the silage from agricultural by-products were studied in two experiments. The first experiment was conducted to investigate the chemical composition and degradability of various silages with varying ensiling times. The experiment was a 5×3 factorial design, completely randomized, with factor A as the different formulated mixtures by varying level of urea addition (0, 0.5, 1.0, 1.5 and 2.0%) and factor B as the time of ensiling. Chemical composition changed little with time and varied only slightly with levels of urea in the mixtures. Dry matter (DM) degradability increased with increasing cassava levels while crude protein degradability and pH level increased with increasing urea addition. By using 'Flieg point', which relates to organic acid yields, there were no significant difference among ensiled mixtures and times of ensiling. Therefore it can be concluded that the 5th silage formulation is the most appropriate since its DM and crude protein (CP) degradability were highest. The second experiment was carried out to determine the quality of the 5th silage mixtures (from the previous trial) after being stored for up to 6 months. The experiment was a complete randomized design with samples taken at monthly intervals up to 6 months and subjected to laboratory and degradability analyses. The results showed no significant (p>0.05) difference in chemical composition except for increased neutral detergent fiber and acid detergent fiber percentage in association with increasing storage time. There were no significant (p>0.05) differences in 'Flieg point' among times of storage. In conclusion, this experiment showed that the silage from agricultural by-products can be stored for more than 6 months. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 4 : 473-478)***

Key Words : Silage, Agricultural By-products, Dairy Cattle

INTRODUCTION

In terms of feeding management in Thailand, concentrate is normally offered to the cows before and during milking; locally used roughage such as fresh cut grass, fresh cut maize, maize silage and rice straw are then offered. This method is convenient to small-holder dairy farms. A sharp reduction in rumen pH occurs after the concentrate meal. When roughage is subsequently fed, rumen pH may slightly increase. Such feeding practice can cause a fluctuation in rumen pH and thus reduce microbial activity. Feeding the cows in the form of a complete feed or total mixed ration has a slight effect on rumen pH. Such systems in which the roughage together with concentrates are thoroughly mixed by automated or semi-automated equipment are frequently used in Europe and North America. This practice offers the cows a well-balanced diet, provided that the formulations of total mixed rations are properly calculated to meet the requirement of the cows.

Because forage shortage generally occurs during the dry season, most of the Thai dairy farmers feed their cows with agricultural by-products, mainly rice straw. However, the use of such by-products has limitations due to their low nutritive value. Recently, rice straw and sugarcane bagasses have been used as dairy cattle feed in the form of roughage mixtures (Suksombat, 1997; 1998a,b). Suksombat (1997) determined the effect of feeding 4 different roughage mixtures on dairy cow performance in late lactation. The result showed that cows on all roughage-mixed rations gave reasonable milk production i.e. 8.3 to 9.3 kg/cow daily. Subsequent research (Suksombat, 1998a,b) compared one fresh forage and 3 roughage-mixed rations in respective early and mid lactation during the rainy season. They concluded that cows receiving fresh forage produced higher milk yield than from cows receiving roughage-mixed rations but the difference was not significant. More recently, Suksombat (1999; 2000) researched the effect of feeding one fresh forage and 3 roughage-mixed rations in respective early and mid lactation during the dry season and concluded that cows fed roughage-mixed rations produced similar milk yield to those cows fed fresh forage. In addition, Suksombat et al. (1999) determined the effect of feeding 3 different total mixed rations, which contained similar ingredients (maize silage, 16% crude protein commercial concentrate, rice straw and bagasse) but in varying proportion. The results showed that yields of milk, milk fat and milk protein were similar in all treatments. Therefore, bagasse and rice straw can be used as fiber sources in roughage-mixed rations and total mixed rations for dairy cows.

Many agricultural by-products can be used to make roughage-mixed and total mixed ration or complete feed. However, only some of them have a high potential since they are presented in large quantities and are convenient to collect. Bagasse, rice straw and brewers' grain are examples

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Table 1. Formulations of ensiled mixtures from various agricultural by-products

	Ensiled complete feed formulation (kg fresh weight)				
	1	2	3	4	5
Bagasse	28.0	28.0	30.0	31.0	33.0
Cassava chip	10.0	14.5	21.0	27.0	33.0
Extracted rice bran meal	40.0	38.0	32.0	26.0	19.0
Brewers' grain	9.0	9.0	7.0	7.0	7.0
Soybean meal	8.0	5.0	4.0	2.5	1.0
Molasses	5.0	5.0	5.0	5.0	5.0
Urea	-	0.5	1.0	1.5	2.0
Total	100	100	100	100	100

of such agricultural by-products. Moreover, these by-products can be used as dairy cattle feed in the form of silage. This research aims to characterize processing, and storage of ensiled agricultural by-products found in Thailand.

MATERIALS AND METHODS

Agricultural by-products

Six selected agricultural by-products were collected from brewers' mill, feed mill and sugar cane mill. These were bagasse, cassava chip, extracted rice bran meal, molasses, brewers' grain and soybean meal. Chemical composition was assessed first. A sample was ground through 1 mm sieve and then subjected to laboratory analyses (AOAC, 1990). Another sample was ground through 2 mm sieve and then subjected to nylon bag DM degradability determination (∅rskov and Mehrez, 1977; Lindberg, 1985).

Ensiled complete feed production

The by-products that had been subjected to laboratory analyses were used to formulate 5 different silage by varying level of urea addition (0, 0.5, 1.0, 1.5 and 2.0%) on a laboratory scale basis (Table 1). They were then thoroughly mixed and placed in airtight plastic bag and poly-ethylene bag respectively. These mixtures were ensiled for 14, 21 and 28 days. The experimental design was thus a 5×3 factorial arrangement, giving a total of 15 treatments with 4 replications in each treatment.

On the end of the respective ensiling time, samples were taken and freeze dried for DM determination. Dried samples were then ground and analyzed for ash, crude protein, fat concentration (AOAC, 1990), for CF, ADF and NDF (Goering and Van Soest, 1970), for pH (pH meter), acetate, butyrate and lactate (High performance liquid chromatograph; HPLC) (Canale et al., 1984) and for DM and CP degradability (∅rskov et al., 1980).

Flieg point was developed by Flieg (1952) quoted by Woolford (1984) in which points are awarded according to the relative amounts of lactic, acetic and butyric acids in silage. That implies that the higher the proportions of lactic and acetic acids to butyric acid the higher the point and the better the quality. After obtaining the values of organic acids from HPLC determination, Flieg points were calculated from the proportion of lactic, acetic and butyric acids (proportion of lactic acid of 54.1-58.0, 58.1-62.0, 62.1-66.0 and 66.1→75% of total acid=19, 21, 23 and 25 points; proportion of acetic acid of 0-20.0, 20.1-24.0, 24.1-28.0, 28.1-32.0 and 32.1-36.0% of total acid=25, 23, 21, 19 and 17 points; proportion of butyric acid of 0-1.5, 1.6-3.0, 3.1-4.0, 4.1-6.0, 6.1-8.0 and 8.1-10.0% of total acid=50, 38, 37, 34, 32 and 30 points respectively). When each point of each proportion of acid was obtained, the values were then added together to get the total Flieg point.

For DM and CP degradability determination, four non-lactating dairy cows, equipped with cannula in the rumen, were used to study the nylon bag degradation. They were fed, at maintenance level, 6 kg DM of roughage mixed rations (10% CP, 9 MJ ME/kg DM), given as two equal meals per day, at 0800 and 1600 h. The rumen degradation value obtained by weighing approximately 3 g DM of individual sample into each of the nylon bags (80×110 mm; pore size 47 μm, Estal Mono, Switzerland). A total of 126 bags (15×6 bags from Exp. 1 plus 6×6 bags from Exp. 2) were suspended in the rumen of each cow prior to the morning feeding. A bag of each sample per silage per animal was incubated in the rumen for 6, 12, 24, 48, 72 and 96 h and then removed and washed in automatic washing machine with gentle speed for 15 min and then dried at 60ºC for 36 h. After weighing each bag individually, four bags (one from each silage, from each incubation time and from each animal) of each sample were pooled to make one representative sample large enough for CP determination. The percentage losses of DM or CP at the arbitrary of time of each silage were then fitted to the model described by ∅rskov et al. (1980) as follows dg=a+b (1-exp^{-ct}) and effective degradabilities were obtained from equation: *Eff_dg*=a+bc/(c+k). Where: ‘a’ is water soluble nutrient extracted by cold water rinsing (0 h bag); ‘b’ is potentially degrade nutrient other than water soluble nutrient; ‘c’ is fractional rate of degradation of feed per hour; ‘t’ is incubation time (h) and ‘k’ is fractional outflow rate (/h).

Storage period of ensiled agricultural by-product mixtures

The duration of storage of ensiled by-products was assessed using formula 5. The feedstuffs were thoroughly mixed, placed in airtight plastic bag and poly-ethylene bag respectively and stored for up to 6 months. The experiment was a complete randomized design, with 6 treatment groups (1 month to 6 month storage) and with 4 replicates in each group. Samples were taken at monthly intervals for up to 6

Table 2. Dry matter content (DM) and chemical compositions in DM of agricultural by-products

	% of DM							*dg*
	DM	CP	Fat	Ash	CF	NDF	ADF	
Bagasse	42.1±0.50	1.5±0.02	2.1±0.29	4.6±0.01	49.6±0.09	85.4±0.23	51.2±0.10	21.2
Cassava chip	87.6±0.30	1.7±0.02	1.7±0.06	2.1±0.06	4.4±0.10	9.7±0.11	1.9±0.03	76.0
Extracted rice bran meal	87.1±0.15	17.2±0.17	3.3±0.06	11.9±0.10	12.7±0.11	50.5±0.10	5.7±0.09	63.2
Brewers' grain	23.7±0.01	28.4±0.51	10.1±0.30	4.6±0.01	15.2±0.08	62.2±0.21	10.0±0.10	62.7
Soybean meal	87.0±0.14	47.5±0.17	3.1±0.29	7.2±0.13	5.9±0.13	15.4±0.15	7.5±0.31	65.7
Molasses	74.6±0.28	2.4±0.19	-	-	-	-	-	-

Values are mean±SD; *dg* are effective degradability of DM (%).
DM, drymatter; CP, crude protein; CF, crude fiber; ADF, acid detergent fiber; NDF, neutral detergent fiber.

Table 3. Dry matter content (DM), chemical compositions in DM and degradability of ensiled mixtures after 14, 21 and 28 days of ensiling

Period	Formula	DM	CP	Fat	Ash	CF	NDF	ADF	*dg* DM	*dg* CP
14 day	1	46.2	16.4	3.9	6.1	19.2	32.2	18.6	45.3	45.6
	2	47.8	15.5	4.7	6.2	17.0	34.5	17.0	52.2	54.1
	3	47.9	15.2	3.3	6.2	15.3	36.3	18.1	54.6	60.2
	4	51.7	14.9	3.9	5.6	16.7	35.9	18.0	59.4	69.3
	5	55.2	15.5	3.5	5.9	15.2	33.1	18.2	60.4	77.9
21 day	1	44.3	15.7	4.7	6.3	17.8	37.3	17.7	44.5	44.4
	2	47.7	14.4	4.4	6.6	14.1	34.1	17.7	50.8	51.9
	3	49.0	14.5	3.8	5.8	14.8	36.7	18.5	55.6	61.6
	4	54.1	13.6	3.5	5.1	12.5	35.9	17.3	54.7	65.1
	5	54.0	15.0	3.1	6.1	13.9	33.4	17.1	57.3	74.2
28 day	1	45.6	16.9	3.9	6.0	15.5	37.2	18.1	49.5	47.5
	2	46.5	14.7	3.9	6.5	14.3	36.0	17.8	52.3	52.8
	3	49.3	14.1	2.8	5.5	14.1	33.7	17.0	57.2	61.9
	4	49.4	15.8	3.3	5.8	15.6	37.4	18.2	51.6	60.9
	5	55.0	13.9	3.2	5.3	13.7	32.9	17.1	60.3	74.3
SEM		0.87	0.81	0.41	0.26	1.02	1.77	1.21	-	-
%CV		2.50	7.61	15.40	6.21	9.37	7.09	9.60	-	-
Ensiled period		0.1818	0.0657	0.0189	0.3070	0.0001	0.9329	0.8032	-	-
Formula		0.0001	0.0033	0.0001	0.0001	0.0001	0.0061	0.8641	-	-
EP×F		0.0003	0.2098	0.3002	0.0051	0.0303	0.6412	0.8385	-	-

DM, dry matter; CP, crude protein; CF, crude fiber; ADF, acid detergent fiber; NDF, neutral detergent fiber; *dg* DM, degradability of DM; *dg* CP, degradability of CP; SEM, standard error of the mean; CV, coefficient of variation; EP, ensiled period; F, formula.

months and analyzed as previously described.

All data obtained were subjected to analysis of variance (ANOVA) by Statistical Analysis System (SAS, 1985).

RESULTS AND DISCUSSION

Bagasse, extracted rice bran meal, cassava chip, brewers' grain and molasses were chosen to use in the present study since they are presented in large quantities and are convenient to collect. Office of Agricultural and Economics (2002) reported 18.0, 6.7, 3.0, 2.1 and 0.12 million tons of bagasse, cassava chip, molasses, rice bran and brewers' grain produced each year respectively. These by-products are considered to have a very high potential to use as cattle feeds (Suksombat, 2001). The different levels of urea were added to balance for N content in the mixtures since urea is one nutrient additive showing promise, as it not only raises the N content of the product but improves its aerobic shelf-life.

Chemical composition of agricultural by-products

Chemical composition and DM degradability of agricultural by-products are shown in Table 2. Bagasse and cassava chip were low in crude protein and fat percentage. Crude protein content was highest in soybean meal, followed by brewers' grain and extracted rice bran meal. Bagasse had the highest acid detergent fiber percentage. Many factors can affect chemical composition of agricultural by-products such as climatology, soil fertility, species, age of harvest, processing etc. However, these chemical compositions were in the same range generally reported in various publications. (Jackson, 1977; Ibrahim and Pearce, 1983; NRC, 1988; Rangnekar, 1988; McDonald et al., 1995; Suksombat et al., 1999; Boonrawd Brewery Co.Ltd., 2000). DM degradability was highest in cassava chip, followed by soybean meal, extracted rice bran meal, and brewers' grain while bagasse had the lowest DM degradability. Ibrahim and Pearce (1983) reported a 32.8% *in vitro* organic matter digestibility (IVOMD) of bagasse

Table 4. pH, organic acids and Flieg point of ensiled mixtures after 14, 21 and 28 days of ensiling

Ensiled period	Formula	pH	g/kg DM			Flieg point
			Lactate	Acetate	Butyrate	
14 day	1	3.95	49.9	10.1	4.0	95.5
	2	3.99	39.2	7.3	nil	99.5
	3	4.01	32.5	5.8	nil	100.0
	4	4.19	30.0	8.8	nil	97.0
	5	4.36	44.6	8.2	nil	98.8
21 day	1	4.05	42.8	8.8	nil	99.5
	2	4.07	37.7	8.5	nil	99.5
	3	4.12	27.1	6.6	1.7	88.8
	4	4.25	27.4	8.3	nil	97.5
	5	4.38	31.2	5.5	0.9	88.0
28 day	1	4.04	32.6	7.5	3.0	82.0
	2	4.11	28.7	7.8	2.9	89.5
	3	4.25	33.7	12.3	nil	95.5
	4	4.33	29.2	13.0	nil	91.4
	5	4.43	27.5	9.4	1.6	92.0
SEM		0.06	4.88	1.44	-	3.90
%CV		2.11	20.10	23.80	-	5.80
Ensiled period		0.0001	0.0006	0.0009	-	0.0001
Formula		0.0001	0.0005	0.0510	-	0.4020
Ensiled period×Formula		0.6938	0.0557	0.0009	-	0.0028

SEM; standard error of the mean, CV; coefficient of variation.

comparing to a 21.2% *dg* DM in the present study. Degradability of feed in ruminants is affected by many factors such as quality, quantity, physical form, particle size and passage rate (Jeon et al., 2003). Jeon et al. (2003) found low digestibility of forest by-product silage relating to high crude fiber contents. The high degradability of cassava chip, in the present study, was expected from its high starch and low fiber contents. Low degradability of bagasse was also attributed to higher content of crude fiber than other by-products.

Chemical composition, degradability, pH and organic acids of ensiled mixtures

Chemical composition and degradability of 5 ensiled agricultural by-products are given in Table 3. The ensiled period did not affect (p>0.05) chemical composition of all ensiled products except for crude fiber and fat percentages which decreased with increasing time of ensiling. By contrast the formulation had a significant effect on chemical composition except for acid detergent fiber concentration. Formula 1 had higher CP, fat and CF contents than other formula while DM content was higher in formula 5 than the other formula. Catchpoole (1962) found a reduction in CP content after ensilage of signal grass (*Brachiaria decumbens*) which was probably because microbial activity degraded CP in to ammonia (McDonald, 1981). A reduction in CP content from formula 1 to formula 5 is probably due to losses in ammonia from urea addition occurring during ensiling process. Johnson et al. (1967) found that urea treatment of corn silage tended to increase the formation of ammonia and reduce the content of crude protein.

In contrast to the results of the present study, the laboratory scale investigations of Mischustin (1969), in which chopped corn was treated with 0.5% urea, revealed that at the lower density the additive retarded fermentation and in the final silage gave increases of protein and amino nitrogen over the control silage of 50-60% and 30-40%, respectively. However, at the higher density urea had no effect on fermentation, protein, or amino nitrogen, although it increased the ammonia content of the silage. Furthermore, it was shown that 55 and 25% of urea was lost in the low- and high-density silage, respectively, although none of the isolates of *Lactobacilli spp.* were able to use urea or ammonia salts as source of nitrogen. Jackson and Anderson (1970) also noted similar changes following the application of 0.4% urea. In spite of some evidence to the contrary, urea seems to have a favorable effect on silage fermentation as well as improving the nutrient value of the end product. In addition, the advantage of reduced acidity is clear because too much free acid can reduce silage consumption.

DM contents of ensiled mixtures were in ascending order while CP contents were in descending order from formula 1 to formula 5. An increase in DM content from formula 1 to formula 5 can be attributable to an increase in cassava chip which contained higher DM content than the other agricultural by-products.

Since feed residues from nylon bags were pooled before analyzing for CP, the statistical analyses for DM and CP degradability were therefore not possible. However, the result showed that DM and CP degradability of formula 5 were numerically higher than other formula.

Table 4 shows values of pH, organic acids and Flieg

Table 5. Dry matter content (DM) and chemical compositions in DM of ensiled mixtures from 1 to 6 mo storage

Storage (month)	% DM	% of DM					
		CP	Fat	Ash	CF	NDF	ADF
1	52.2	12.7	1.98	7.59	12.2	33.8	17.9
2	49.9	12.6	2.06	8.57	14.3	38.4	22.2
3	52.4	12.4	1.91	7.76	13.2	30.8	17.6
4	50.8	12.8	1.94	9.05	13.9	34.2	21.2
5	48.9	12.2	2.19	9.25	13.0	35.7	23.0
6	49.9	12.5	2.12	9.57	12.6	36.9	23.3
SEM	1.91	0.50	0.20	0.83	0.93	1.91	1.10
%CV	7.30	5.68	7.70	13.57	9.90	7.70	7.44
Pr>F	0.4100	0.8916	0.7015	0.1409	0.2694	0.0143	0.0001

DM; dry matter, CP; crude protein, CF; crude fiber, ADF; acid detergent fiber, NDF; neutral detergent fiber, SEM; standard error of the mean, CV; coefficient of variation.

Table 6. pH, organic acids and Flieg point of ensiled mixtures from 1 to 6 mo storage

Storage (month)	pH	g/kg DM			Flieg point
		Lactate	Acetate	Butyrate	
1	4.45	23.23	11.24	1.97	72.8
2	4.67	16.22	10.06	2.56	65.5
3	4.45	24.06	14.79	3.16	67.5
4	5.23	32.20	17.77	4.90	69.0
5	5.06	37.36	16.88	2.41	78.0
6	5.04	23.11	12.59	2.35	72.0
SEM	0.17	4.74	2.14	0.82	5.33
%CV	4.96	25.70	21.70	40.2	10.6
Pr>F	0.0004	0.0047	0.0103	0.0269	0.2718

SEM; standard error of the mean, CV; coefficient of variation.

point of the ensiled mixtures. Ensiled periods had significant effects on pH, organic acids and Flieg point. The pH increased while lactic acid production and Flieg point decreased with increasing time of ensiling. During the early stage of fermentation, the coliform bacteria are active. These organisms multiply until about the seventh day after ensilage and then decrease in numbers. Following this period they are progressively replaced by the slower growing high acid-producing *Lactobacilli*. The pH of the silage drops as a result of high lactic and acetic acids produced. The result of the present study showed lower pH but higher lactic and acetic acid yield at 14 days ensilage. Following the first two weeks of ensiling the pH increased while acid productions declined with increasing time of ensiling. A reduction of lactic acid with increasing time of ensiling can be attributed to the utilization of lactic acid produced by *Lactobacilli* during the early fermentation by other microorganisms. Formulation also had significant effects on pH and lactic acid production but not on acetic yield and Flieg point. Increases in the addition of urea to ensiled mixtures from formula 1 to formula 5 resulted in increased urea degradation to ammonia. The pH therefore increased with increasing urea addition (Shirley et al., 1972; Huber et al., 1979).

Storage of ensiled mixtures

Chemical compositions of ensiled mixtures stored from 1 to 6 months are given in Table 5. There were no significant difference in DM, CP, fat, ash and CF between times of storage. However, NDF and ADF percentages significantly fluctuated during storage. A fluctuation in NDF and ADF content during storage depended largely on the pattern of microbial fermentation and on materials ensiled. Ely et al. (1981) and Chauhan and Kakkar (1981) found decreased NDF and increased ADF with increasing time of storage. Microorganisms utilized some NDF during ensilage but not with ADF. NDF content therefore reduced and ADF content increased.

Table 6 shows values of pH, organic acids and Flieg point of ensiled mixtures stored for up to 6 months. Levels of pH increased with increasing time of storage. Production of organic acids all increased with increasing time of storage up to 4-5 months then declined at 6 months storage. Flieg points were not significantly different due to time of storage and were classified as good quality ensiled mixtures.

IMPLICATION

This research indicates that some agricultural by-products have a high potential to improve quality and to utilize the various forms of dairy cattle's feeds particularly in the form of silage. Well-balanced nutrient ensiled by-products need to be fermented for at least 14 days provided that optimum level of brewers' grain and molasses is added, and moisture content is adequate to enhance fermentation process. This research also found that balanced nutrient ensiled mixtures can be stored for more than 6 months. The dairy farmers in Thailand and/or elsewhere can obtain these results of the study to make silage from agricultural by-products and feed to the cows during the shortage of fresh forage.

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