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EFFECTS OF ENSILING TIME ON BANANA PSEUDO-STEM SILAGE CHEMICAL COMPOSITION, FERMENTATION AND *IN SACCO* RUMEN DEGRADATION

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ABSTRACT

The study was planned to check the effect of time on dynamics of fermentation, chemical composition and rumen degradation in banana pseudo-stems silage (BPSS). For this purpose banana pseudo-stem (BPS) was ensiled for 0, 20, 30, 40, 50, 60, 70, 80 and 90 days in polyethylene bags. Each time point had three replicates. After 0, 20, 30, 40, 50, 60, 70, 80 and 90 days triplicate polyethylene bags were opened for chemical analysis and fermentation characteristics. Water-soluble carbohydrates (WSC) significantly decreased (19.75±0.53, 7.25±0.09 g kg^{-1} at day 20 and 30 respectively) after ensiling (P<0.05) but consistency was achieved at 50 day of fermentation to onward. After 50 days of fermentation, crude protein (CP) was increased (52.45±0.63 g kg^{-1} at day 60) significantly (P<0.05). The pH decreased (P<0.05) at day 30 and consistency was achieved on the subsequent days. Ammonia-nitrogen (NH_3-N) showed increasing trend at day 30 and 40 but there was no changing trend on the following days. Lactic acid production was increased (P<0.05) 31.22±0.42and 31.04±0.71 g kg^{-1} at day 30 and 40 respectively after ensiling and highest lactic acid production was noted at day 80 (51.97±3.09). Only small amounts of butyric acid, isobutyric acid, and propionic acid were detected in the BPS after 50 days. The rumen degradability of banana pseudo-stems (BPS) and BPSS at 80 days of fermentation were studied *in sacco* in three ruminally cannulated adult Xia'nan cattle (570 ± 23 kg) at 6, 12, 24, 36, 48 and 72 h of incubation periods. The effective degradability (ED) of BPS, neutral detergent fiber (NDF) was higher than that of BPS0. Although the fermentation did not improve ED of DM and CP in BPS, a lower terminal pH, and higher concentration of lactic acid might enhance aerobic stability after opening the silage.

Key words: banana pseudo-stem, silage, fermentation, ruminal degradability.

INTRODUCTION

Grains production for increasing human population reduces land for ruminants fodder cultivation. Increasing demands of milk and meat specifically in China and in world generally encourage farmers to find alternative forages. In this era some agricultural by-products of low nutritive value seems to alternative of fodder shortage and banana pseudo-stem (BPS) is one of main by-product. The banana plant is an herbaceous perennial species of the Musa family, characterized by stems of up to 5 m in length and broad leaves. The banana plant represents a very interesting example of a multi-purpose plant that is widely grown as a fruit crop in both tropical and subtropical regions. The leading banana and plantain producers in the world are India, China, Uganda, Ecuador, the Philippines, and Nigeria (Padam *et al*., 2012). Studies examining the potential uses of BPS have shown good productive and qualitative characteristics. Direct substitution of banana leaves and pseudo-stems (*Musa paradisiaca*) as forage for Ovin Martinik sheep had no significant effects on carcass weight and yields (Marie-Magdeleine *et al*., 2009). Liu *et al.* (2013) hasreported that banana stems and leaves can be directly ensiled for two months and can be used for short-term storage without dehydration. However, information on the nutritive value of BPSS is lacking.

The chemical composition of forage changes after silage fermentation. Mthiyane *et al*. (2001) reported that the crude protein (CP), neutral detergent fiber (NDF), ethyl ether extract (EE), and mineral substance contents of sugarcane tops differ significantly pre- and post-ensiling. The chemical composition may also be affected by the silage time. Bagheripour *et al*. (2008) reported that the silage water-soluble carbohydrates (WSC), NDF and acid detergent fiber (ADF) contents of pistachio by-products declined with increasing fermentation time.

Banana pseudo-stem is being used in China as a forage source in the form of silage. However, information on nutritive value of BPS on different incubation period is lacking. Banana pseudo-stems have already been estimated through *in sacco* measurements (Katongole *et al*., 2008), but less information is available about the *in sacco* BPSS. This study was planned to check the possibility of ensiling BPS at different ensiling time on preservation quality (fermentation product and chemical composition) and rumen degradation.

MATERIALS AND METHODS

Collection and processing of banana stalks: Banana plants were randomly sampled from a banana plantation after harvesting of the fruit. Banana plants were cut down at ground level and then sectioned. The samples were cut into 2-3 cm-long pieces.

For each time point, three polyethylene bags were used, 2 kg each, which were inserted into a plastic bucket, pressed and sealed. The bags were filled and weighed immediately. Bags were stored at 25°C for 0, 20, 30, 40, 50, 60, 70, 80 and 90 days in dark place. Day was taken as treatment and each treatment had three replicates. Each replicate was opened and analyzed at the respective days.

Weighed pre-silage materials and silage with twice the weight of water added were pulverized with a juicer and filtered. The collected filtrate in a conical beakers was used to measure pH. The samples to be used for the determination of ammonium nitrogen, lactic acid and volatile fatty acids (VFAs) were frozen at -35°C. Other samples were dried, ground and mixed, and the fractions that passed through 1 mm screen were further used for chemical analysis.

Analytical methods: The dry matter (DM) of ground samples were determined by drying the sample at a constant temperature of 105°C for 5 h in a hot air oven. The CP, EE, ash and phosphorus (P) contents were quantified according to AOAC procedures (1999), using method numbers 984.13, 920.30, 942.05 and 995.11, respectively. The calcium content (Ca) was measured via atomic absorption spectrometry. The acid detergent fiber (ADF) and NDF contents were determined by using Van Soest *et al*. (1991) method. Anthracenone-vitriol colorimetry determination was conducted to determine the contents of WSC using dried samples (McDonald *et al*., 1964).

Spectrophotometric method was used to determine total phenol (TP) and total tannin (TT) contents (Makkar *et al*., 2007). TP and TT were expressed as tannic acid equivalents. The amount of total tannins was measured by subtracting contents of phenolics before and after the removal of tannins from the extract using polyvinyl pyrrolidone. The amount of condensed tannin (CT) was measured with the butanol-HCl-Fe^{3+} reagent (Porter *et al*., 1986) and expressed as leucocyanidin equivalents.

The silage pH was measured with a pH meter (pH meter UB-7, Denver Electronics Ltd., Denver, USA). Ammonia-nitrogen (NH_3-N) was determined via a phenol-hypochlorite spectrophotometric method, as described by Broderick and Kang (1980). The analysis of lactic acid was performed according to the method of Barker and Summerson (1941).

VFAs, including acetate, propionate, butyrate, isobutyrate, valerate and isovalerate, were analyzed by the methods of Erwin *et al*. (1961), with slight modifications.

Animals and *In situ* degradability: Three adult Xia'nan cattle (570 ± 23 kg) with permanent ruminal cannula (Bar Diamond Inc., Parma, Idaho, USA) were used for sample incubation. Eighty days ensiled BPSS was used for the rumen degradation experiment.

Ørskov *et al*. (1980) method was used to determine the *In situ* degradability. Nylon bags (8 cm×12 cm) with a 50 µm-diameter pore size were used in this study. Four grams of grounded sample were put in the. Duplicate bags were incubated in the rumen of each animal for 6, 12, 24, 36, 48 and 72 h. The bags were washed with tap water and then dried to at 65°C in a forced-air oven, until constant weight obtained.

Calculations and statistical analysis: The data obtained were analyzed using the general linear model (GLM) procedure in SAS 9.1 (SAS Institute Inc., Cary, NC). Statistically significant differences were tested using Duncan's method.

After Applying the PROC NLIN procedure, the data of degradation was putted in the equation $P = a + b (1-e^{-ct})$ (Ørskov and McDonald, 1979) to determine degradation characteristics (a, b and c). In equation $P = a + b (1-e^{-ct})$, P is the degradation at time t; a + b is the potential degradability of the feed when time is not limited; a is the soluble fraction of the feed; b is the slowly degradable fraction; and c is the rate of degradation of the slowly degradable fraction. The calculation of effective degradability (ED) was determined by using the equation of McDonald (1981): $ED = a + bc / (c + k)$. In equation $ED = a + bc/ (c + k)$, k is the estimated ruminal passage rate, and a, b and c are the parameters as presented in previous equation. Effective degradability was calculated by using the rate of 0.08, 0.06, and 0.02, per hour, which are representative of high, medium, and low feeding levels, respectively (Agricultural Research Council, 1984).

RESULTS

Quality characteristics: The DM content was 9.77±0.16%. Based on the DM content, the WSC, CP, EE, NDF, ADF, ADL and ash contents were 78.35±0.17, 27.90±0.63, 68.64±2.50, 353.23±9.52, 164.35±2.03, 35.16±1.79 and 108.11±0.40 g kg^{-1}, respectively. The concentrations of Ca and P were 3.24±0.03 g kg^{-1} and 1.02±0.02 g kg^{-1}, respectively, and the concentrations of TT and CT were 2.20±0.03 and 1.76±0.008 g kg^{-1}, respectively.

Effect of time on ensilability characteristics: The chemical composition of the BPSS is in Table 2. DM did

not change significantly during the entire silage fermentation period. However, the time of ensiling had a significant effect on WSC, CP, NDF, ADF, TT and CT. The results showed that WSC significantly decreased (19.75±0.53, 7.25±0.09 g kg^{-1} at day 20 and 30 respectively) after ensiling (P<0.05) but from 50 days to 90 days WSC contents were same. After 50 days of fermentation, CP was increased significantly (P<0.05), but no significant changes were observed in ADF, TT and CT. The NDF was increased significantly after 20 days of fermentation (P<0.05). Compared with the 40th day of ensiling with day 50 the ADF was significantly decreased (183.74±10.18 vs 136.95±14.07 g kg^{-1}, P<0.05), while TT and CT were significantly increased (1.38±0.04 vs 2.80±0.23 g kg^{-1}; 1.70±0.03 vs 1.86±0.007 g kg^{-1}, P<0.05). After 50 days of fermentation, no obvious changes in any of the composition parameters were detected during ensiling.

Fermentation quality of the silages: The changes in pH, lactic acid concentrations and the fermentation end product profile observed during the course of ensilage are in Table 3. The results represents that for the entire ensiling period, there were significant changes in pH, NH_3-N and lactic acid. However, no significant changes in the propionic acid, acetic acid, butyric acid, and isobutyric acid concentrations were detected. The pH level was decreased (P<0.05) at day 30 and remained unchanged on the subsequent days. Ammonia-nitrogen (NH_3-N) showed increasing trend at day 30 and 40 but there was no changing trend on the following days. Lactic acid production was increased (P<0.05) 31.22±0.42 and 31.04±0.71 g kg^{-1} at day 30 and 40, respectively after ensiling and highest lactic acid production was noted at day 80 (51.97±3.09). After 50 days of fermentation, no obvious changes in the concentration of any substance were detected.

Ruminal degradation: The degradation recorded in the rumen after 6, 12, 24, 36, 48 and 72 h of incubation is shown in Fig. 1. After 48 h of incubation, the disappearance rates of DM, CP, TT and CT in BPSS were all higher than in BPS. The disappearance rate of NDF in BPSS was higher than BPS throughout the incubation period. In contrast, the disappearance rate of ADF in BPSS was lower than BPS during incubation. The rumen degradability parameters are summarized in Table 4. The readily available soluble fraction (a), slowly degradable fraction (b), degradation rate (c) and effective degradability (ED) differed markedly between the compositions of BPS and BPSS. The soluble fractions of DM, ADF, CP, TT and CT in BPS were all higher than BPSS; only the readily available soluble fraction of NDF was lower. The slowly degradable fractions of all parameters were lower in BPS than in BPSS. The degradation rates of DM, NDF, CP, and CT in BPS were lower than in BPSS, whereas the degradation rates of ADF and TT were higher in BPS. With the exception of the ED of NDF in BPS, which was higher than in BPSS, the ED for the remainder of the degradation parameters was lower in BPS than in BPSS.

Table 1. Chemical composition of pre-ensiled banana pseudo-stems

Item	Mean
Dry matter (g kg^{-1} FM)	9.77±0.16
g kg^{-1} DM	
Water-soluble carbohydrates	78.35±0.17
Crude protein	27.90±0.63
Ethyl ether extract	68.64±2.50
Neutral detergent fiber	353.23±9.52
Acid detergent fiber	164.35±2.03
Acid detergent lignin	35.16±1.79
Ash	108.11±0.40
Calcium	3.24±0.03
Phosphorous	1.02±0.02
Total tannins	2.20±0.03
Condensed tannins	1.76±0.008

SEM: Standard error of the mean

Table 2. Banana pseudo-stem herbage characteristics after different fermentation times

Item	Days of ensiling									SEM	*P*-value
	0 d	20 d	30 d	40 d	50 d	60 d	70 d	80 d	90 d		
DM(%FM) g kg^{-1} DM	9.77±0.16	10.05±0.16	9.33±0.55	9.63±0.19	9.55±0.32	9.25±0.24	9.56±0.08	9.67±0.04	9.37±0.27	0.26	0.222
WSC	78.35±0.17^{a}	19.75±0.53^{b}	7.25±0.09^{d}	11.15±1.20^{cd}	20.10±2.40^{b}	16.85±2.61^{bc}	20.70±0.14^{b}	17.85±0.21^{bc}	15.60±0.14^{bc}	2.18	<0.001
CP	27.90±0.63^{c}	28.20±1.41^{c}	26.40±0.70^{c}	28.65±2.33^{c}	46.70±1.55^{b}	52.45±0.63^{a}	51.60±0.42^{a}	48.90±2.54^{ab}	48.90±0.14^{ab}	1.40	<0.001
NDF	353.23±9.52^{b}	542.64±21.92^{a}	449.03±10.00^{ab}	433.75±20.16^{ab}	516.37±18.80^{ab}	513.82±17.64^{ab}	399.40±5.37^{ab}	463.15±6.85^{ab}	484.96±6.11^{ab}	43.62	0.030
ADF	164.35±2.03^{ab}	184.47±12.44^{a}	172.38±1.83^{ab}	183.74±10.18^{a}	136.95±14.07^{b}	156.61±5.44^{ab}	141.43±9,75^{b}	144.94±13.64^{b}	158.08±4.35^{ab}	10.44	0.009
TT	2.20±0.03^{abcd}	1.65±0.11^{bcd}	1.11±0.02^{d}	1.38±0.04^{cd}	2.80±0.23^{ab}	2.57±0.17^{abc}	2.23±0.18^{abcd}	1.99±0.22^{abcd}	2.97±0.06^{a}	0.35	0.005
CT	1.76±0.008^{ab}	1.84±0.007^{a}	1.76±0.05^{ab}	1.70±0.03^{b}	1.86±0.007^{a}	1.72±0.04^{b}	1.72±0.03^{b}	1.72±0.02^{b}	1.82±0.006^{ab}	0.03	0.005

SEM: Standard error of the mean.

Note: Means within the same row with different lowercase superscripts differ significantly ($p<0.05$).

DM (% FM): dry matter. The following parameters were reported on a dry matter basis: WSC (g kg^{-1} DM): water-soluble carbohydrates; CP (g kg^{-1} DM): crude protein; NDF (g kg^{-1} DM): neutral detergent fiber; ADF (g kg^{-1} DM): acid detergent fiber; TT (g kg^{-1} DM): total tannin as tannic acid equivalents; CT (g kg^{-1} DM): condensed tannin.

Table 3.Fermentation end product profile of banana pseudo-stems silage

Item	Days of ensiling								SEM	
	20 d	30 d	40 d	50 d	60 d	70 d	80 d	90 d		*P*-value
pH	5.09±0.21^{a}	4.43±0.13^{b}	3.97±0.12^{b}	4.13±0.08^{b}	3.99±0.09^{b}	4.07±0.21^{b}	3.93±0.19^{b}	4.01±0.34^{b}	0.19	0.005
NH_3-N(%TN) g kg^{-1} DM	14.26±0.10^{c}	27.26±2.68^{a}	20.18±0.08^{b}	16.52±1.46^{bc}	14.46±1.43^{c}	16.12±0.39^{c}	16.99±2.59^{bc}	15.72±2.62^{c}	1.52	<0.001
Lactic acid	10.83±0.42^{d}	31.22±0.42^{bc}	31.04±0.71^{bc}	24.36±2.13^{cd}	43.94±1.30^{ab}	28.45±3.25^{bcd}	51.97±3.09^{a}	42.83±6.62^{abc}	0.76	0.012
Acetic acid	7.67±0.21^{b}	7.86±0.85^{b}	15.59±0.47^{a}	12.36±1.67^{ab}	10.93±0.38^{ab}	8.63±0.89^{ab}	7.44±1.38^{b}	11.92±1.73^{ab}	0.29	0.186
Propionic acid	—	0.83	—	—	0.85	0.81	1.69	2.53	0.11	0.398
Isobutyric acid	0.03	—	—	—	—	—	—	0.05	0.003	0.559
Butyric acid	—	1.92^{a}	—	0.61^{ab}	0.36^{ab}	0.84^{ab}	0.63^{ab}	—	0.06	0.176

SEM: Standard error of the mean.

Note: '—' not undetected. Means within the same row with different lowercase superscripts differ significantly ($p<0.05$).

Means within the same row with different lowercase superscripts differ significantly ($p<0.05$).

NH_3-N: ammonia nitrogen, (g kg^{-1} TN).

Table 4. Ruminal degradability characteristics of banana pseudo-stems

		Fractions			c(h^{-1})	Effective degradability at passage rate		
		a	b	(a+b)		0.02h^{-1}	0.06h^{-1}	0.08h^{-1}
DM	Stem	0.653	0.234	0.887	0.023	0.777	0.717	0.704
	Silage	0.516	0.481	0.997	0.026	0.789	0.662	0.634
CP	Stem	0.629	0.145	0.773	0.016	0.692	0.658	0.652
	Silage	0.325	0.674	0.999	0.023	0.686	0.512	0.476
NDF	Stem	0.271	0.310	0.580	0.018	0.418	0.342	0.328
	Silage	0.301	0.409	0.710	0.040	0.573	0.464	0.436
ADF	Stem	0.266	0.335	0.602	0.021	0.439	0.354	0.336
	Silage	0.112	0.375	0.487	0.016	0.280	0.192	0.175
TT	Stem	0.367	0.245	0.612	0.035	0.523	0.457	0.442
	Silage	0.014	0.958	0.971	0.021	0.503	0.261	0.212
CT	Stem	0.670	0.291	0.961	0.015	0.795	0.728	0.716
	Silage	0.542	0.458	1.000	0.027	0.804	0.684	0.657

DM (% FM): dry matter. The following parameters were reported on a dry matter basis: CP (g kg^{-1} DM): crude protein; NDF (g kg^{-1} DM): neutral detergent fiber; ADF (g kg^{-1} DM): acid detergent fiber; TT (g kg^{-1} DM): total tannin as tannic acid equivalents; CT (g kg^{-1} DM): condensed tannin.

a is the soluble fraction of the feed; b is the slowly degradable fraction; a + b is the potential degradability of the feed when time is not limited; c is the rate of degradation of the slowly degradable fraction.

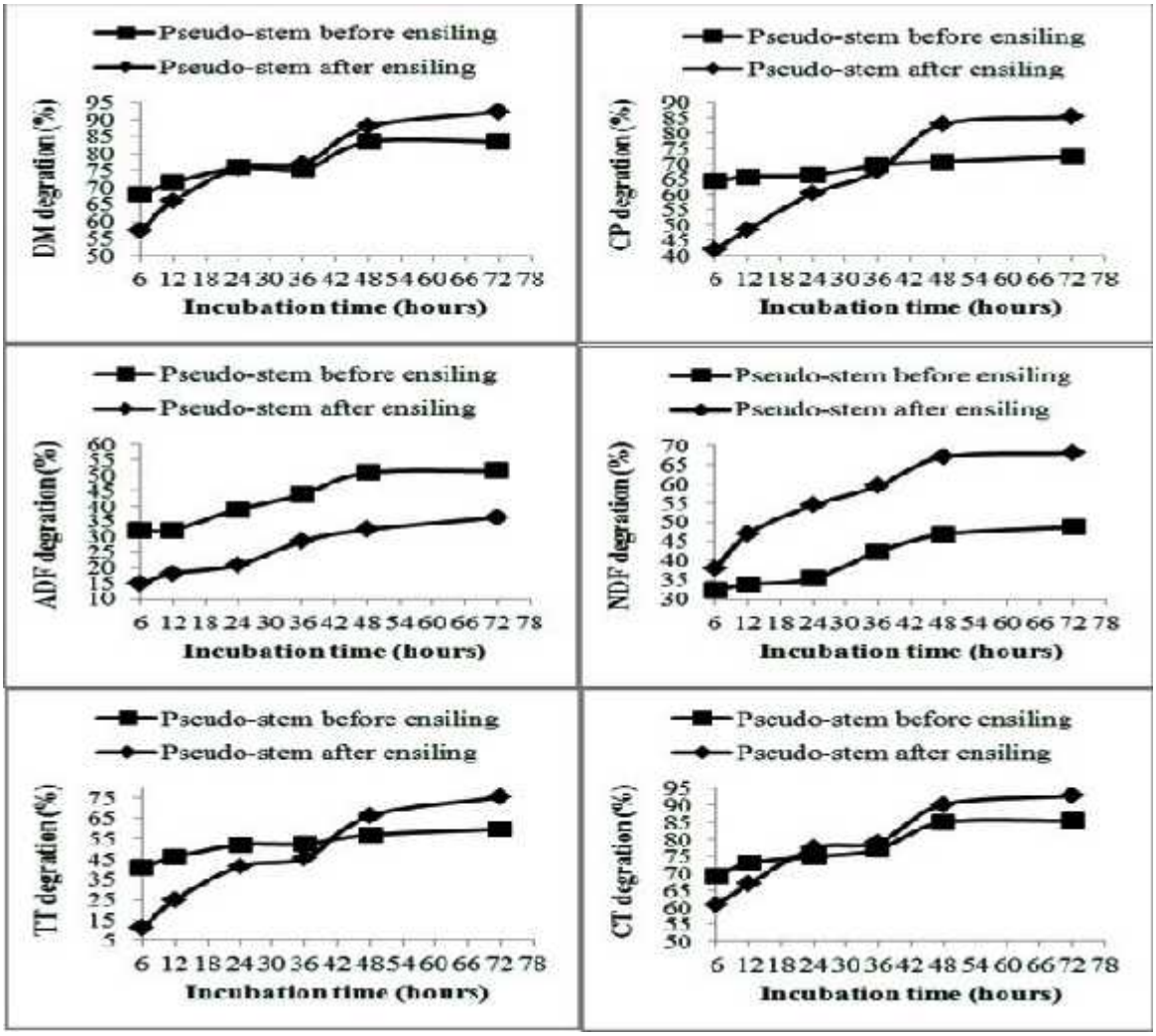

Fig. 1. Disappearance rates in banana pseudo-stems

DISCUSSION

Chemical composition of banana pseudo-stem before ensiling: Our results showed that the fresh BPS exhibited high moisture content, in agreement with the findings of Li *et al*. (2010). Concentrations of WSC in BPS (78.35±0.17 g kg^{-1}, Table 1) were adequate for producing good quality silages (Haigh, 1990). In addition, the observed CP, NDF and ADF values were lesser than those described by Poyyamozhi *et al*. (1986) and Viswanathan *et al*. (1989). Reasons for this inconsistency are unclear. However, several differences existed between the two studies. Firstly, the forages were grown in two different locations and stage of maturity, fertilization and environmental conditions may also reason of change of CP, NDF and ADF of BPS. In contrast, the recorded lignin levels were lesser than those reported by Cordeiro *et al*. (2004). These differences might due to the harvest time, because the relative proportion of the cell wall components of a plant rises with increased maturity, as the comparative proportion of the cell contents declines. The tannin content in the BPS was much lower than that reported in some browse tree foliage, which can be used for sheep and goats (Salem *et al*., 2006). Consequently, BPS also can be used in ruminant diet.

Changes in chemical composition of banana pseudo-stem after ensiling: In the present study, the DM losses did not exceed 5 g kg^{-1} DM during the time of preservation. These values were much lower than the typical maximum losses for acceptable lactic acid fermentation of a grass crop (approximately 40 g kg^{-1} DM) (McDonald *et al*., 1991). The decrease in WSC recorded in BPSS. Differences in WSC concentration of BPS and BPSS are likely due to the increased population of lactic acid production bacteria. Although lactic acid bacteria (LAB) count was not the part of study but higher production of lactic acid is the indication of dominant population of LAB. Faster decline in WSC concentrations has also been reported for barley and alfalfa (Kung *et al*., 1991; Rizk *et al*., 2005) silages. While lower pH in this study was might be due to higher production of the Lactic acid production. No significant change in CP was observed in the BPSS from the first to the 40th day of fermentation. However, the amount of CP began to increase from 50th day of ensiling and was maintained as compare to BPS (Table 2). Our findings are in agreement with f Akinyele and Agbro (2007) who found the protein content of food increases after silage fermentation. Rasool *et al*. (1996) found rise in the percentage of the cell wall fraction during fermentation process. This argument is reinforced by the detected NDF content of the BPSS. An increasing time of ensiling slightly decreased the ADF content, which might have been due to the hydrolysis of a small amount of cellulose during ensiling. This finding is consistent with Yahaya *et al*. (2002), who found that the hemicellulose and cellulose concentration of ensiled orchard grass were lesser as compare with fresh grass.

Fermentation characteristics of banana pseudo-stem after ensiling: A high lactic acid level and a low pH (pH<4.2) are important factors that guarantee successful silage preservation (Bolsen *et al*., 1996). The pH level was maintained at approximately 4.2 after 30 days of ensiling, which indicated that BPS could be successfully ensiled. During early silage, BPS could provide a sufficient substrate for lactic acid bacterial fermentation to occur. As silage seepage comprises WSC and proteins (McDonald *et al*., 1991), *Lactobacillus* would rapidly reproduce by producing lactic acid from WSC, leading to a sharp decline in pH. After 30 days of fermentation, little WSC remains to suppress the growth of *Lactobacillus*. At this time, the ensilage process stabilizes, and the pH and lactic acid levels in silage are maintained at a constant level, inhibiting the growth of spoilage microorganisms (Knický and Martin, 2005). In the present study, acetic acid levels increased during fermentation and remained constant between days 20 and 30. This finding indicated that, although silage fermentation was mainly due to homofermentative lactic acid bacteria, a small amount of acetic acid was also present due to heterofermentative lactic acid bacteria (Hassanat *et al*., 2007). The rapid rise in the acetic acid concentration observed after 30 days of fermentation implied that homogeneous lactic acid fermentation had changed to heterogeneous lactic acid fermentation.

The amount of NH_3-N/TN increased significantly between days 20 and 30 was likely due to the degradation of protein by plant proteinases during early fermentation. NH_3-N was produced by microbial degradation of amino acids. Well-preserved silage should contain less than 10% NH_3-N/TN (McDonald *et al*., 2002). Although the NH_3-N/TN content of the BPSS was more than half of this amount, neither mold, nor rotten odor was detected during the experiment. Instead, a slight alcoholic odor was present in the silage. After 50 days of fermentation, the concentration of NH_3-N/TN did not change significantly. However, a small amount of butyric acid was detected from days 50 to 80. But the growth of *Clostridium* is inhibited when the pH is lower than 4 (Woolford, 1984). In our experiment, the pH level in the BPSS was lower than 4 at day 60 of fermentation, but a small amount of butyric acid was still detected in the silage. Masuda *et al*. (2002) reported that high moisture content facilitates the growth of butyric acid bacteria. As the BPS exhibited high moisture content, Masuda's results may account for the presence of a small amount of butyric acid.

The exceptionally good fermentation pattern obtained in this study without additives, in silage with aDM content lesser than 150 g kg^{-1} fresh matter (FM),

suggests that some BPS constituents may enhance silage preservation.

Ruminal degradation: After 50 days of ensiling, the fermentation of BPSS stabilized. Banana pseudo-stem fermented for 80 days was used for the rumen degradation experiment. Ensiling increased the disappearance rates of substances in the BPS, which indicated that BPSS could increase real-time digestibility in the rumen and could be fed to ruminant animals (Fig. 1). The decreasing disappearance rate of ADF in the BPSS might have been a consequence of the decline in ADF after ensiling. The ED and the rapid soluble fraction of DM in BPS showed significantly higher levels than in BPSS, but the content of the slowly degradable fraction was markedly lesser than in, possibly due to the decline in WSC during fermentation. Before ensiling, BPS show a high WSC content that is easily utilized by rumen bacteria. However, fermentation decreases WSC while increasing hemicellulose. The utilization rate of hemicellulose by rumen bacteria was lower than that of WSC, which could explain the lower ADF and the higher of NDF degradability of the silage. The lower *in sacco* degradability of ED of DM, CP, ADF, TT and CT after ensilage could be due to the tannins effect on available N in the pseudo-stems. This tannin can reduce the rumen ammonia concentration and microbial growth and activity (Salem *et al*., 2007). Furthermore, cross-linkage of tannins to polysaccharides, hemicellulose, and proteins might also inhibit digestibility (Goel *et al*., 2005). In the present study, the CP and NDF contents were higher after ensiling, which could explain the lower TT and CT degradability of the silage.

Conclusion: Banana pseudo-stems can be used as preserved forage for the dry and winter seasons. The good preservation quality of the direct silage in laboratory bags showed that banana pseudo-stems are suitable for preservation by ensiling. The ensiled banana pseudo-stems stabilized after 50 days of fermentation. The high WSC content of the herbage facilitated acceptable lactic acid fermentation, leading to a low pH level in the silage, inhibiting Clostridial activity. Although these changes in the silage composition did not improve the rumen degradability of silage DM, CP and ADF, they might improve the aerobic stability of the silage upon feed-out. Our results show that banana pseudo-stems could be considered as an alternative of traditional forage sources or part of forage source. Further research is required to define the most appropriate agronomic techniques to be applied as well as the preservation quality in farm-scale silos and animal performance.

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