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Nutritive Value and Fermentation Quality of the Silage of Three Kenaf (*Hibiscus cannabinas* L.) Cultivars at Three Different Growth Stages

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ABSTRACT

This study was conducted to evaluate the nutritive value and the quality of ensiled kenaf after fermentation with three cultivars at three different times of harvesting. Experimental plot were allocated with three harvest date (Early;8/3, medium;8/15 and late;8/28) and three cultivars (Tainung-a, Everglade, Whitten). The DM (dry matter) yield increased with maturity in all three cultivars, especially in Whitten which showed the highest yield at each harvest time. The DM content in Whitten at late harvesting time was higher than other treatments (231 g kg^{-1}DM). The CP (crude protein) contents of the kenaf silage of all three cultivars ranged from 151 to 164 g kg^{-1}. Highest content of NDF (neutral detergent fiber) was observed in Everglade at medium harvesting date, but the ADF (acid detergent fiber) content was highest in Everglade at early harvesting date ($p<0.05$). All treatments produced a pH less than 4.0, which is sufficient for stable storage. The pH of Tainung-a was higher than other cultivars at all harvesting times ($p<0.05$). Whitten showed the higher content of lactic acid (25.8 g kg^{-1} DM) showed at early harvesting date than other cultivars ($p<0.05$), while the acetic acid content (21.1 g kg^{-1} DM) was higher in Tainung-a at medium harvesting date ($p<0.05$). No significant difference was observed in ammonia-Nand butyric acid concentrations among all treatments. These results indicate that a kenaf silage could be used as fodder for ruminants. Especially, the Whitten harvested at late growing stage showed promise as a forage silage crop under Koran environments.

(**Key words** : Kenaf, Nutritive value, Fermentation, Silage)

Ⅰ. INTRODUCTION

Kenaf is an annual fiber crop which is adaptable to a broad range of soil types and climates including tropical and sub-tropical areas (Dempsey, 1975). Kenaf plants are capable of growing to a height of 6 m under favorable conditions; however, heights generally average 2.5~4.5 m in a growing season of 4 to 5 months. Traditionally kenaf has been utilized in the production of textile fiber and considered as raw material for the production of cellulose pulp to be used in the paper industry. Despite kenaf's fiber crop origins (Taylor and Kugler, 1992), its potential as s ruminant animal feed has been recognized (Swingle et al., 1978; Wildeus et al., 1995), especially as a silage (Xiccato et al., 1998).

When kenaf is immature, its nutrient profile can compare with that of alfalfa (Suriyajantratong et al., 1973). The CP content of kenaf leaves has been reported to be around 30% (Killinger, 1969; Suriyajantratong et al., 1973; Wing, 1967), and the maximum leaf to stem ratio occurs at

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60 d after planting (Dicks et al., 1992). When harvested at 45 day, the NDF and ADF values were reported to be 47.1 and 31.0%, respectively (Hollowell & Baldwin, 1997), which corresponds to forage that are considered high quality. According to the results from the study of Han et al. (2006) which were observed under Korean environment, the contents of NDF and ADF did not significantly increase with the growth maturity of kenaf (Tainung, Everglade and Dowling). The chemical compositions and nutrition values of the immature kenaf and mature kenaf/crabgrass hays were evaluated relative to alfalfa hay (Hancock et al., 1993). However, the palatability to cattle has often been cited as limiting its future as a forage, although a higher yield and quality of kenaf showed the potential under the shortages of feedstuffs in many countries (Hancock et al., 1993). However, the utilization of kenaf as a silage showed the one of solution to overcome its poor palatability in animal feeding (Xiccato et al., 1998).

Although some studies reported the chemical composition of the kenaf forage throughout years, data on the amount and quality of forage produced by kenaf when preserving as silage with different cultivars is not much available. If any, most of data were observed from the experiments conducted under tropical or sub-tropical environments. Especially, under the environment of Korea there is no study about the forage nutritive value and fermentation quality of the ensiled kenaf. Therefore, the objective of this study was to provide an assessment of the fermentation processes of the kenaf silage through determining the nutritive value and fermentation quality of three different cultivars of the ensiled kenaf harvested at three different growth stages.

Ⅱ. MATERIALS AND METHODS

The kenaf we used in this experiment was grown at Kangwon National University Experiment Farm in Chuncheon, Kangwon province located in north-central South Korea and experimental period was started from 18 April 2011 (planting date) and ended in 28 August 2011 (last harvesting date). Manure was spread before planting and no fertilization was added after planting.

1. Experimental design

Experiment was conducted as a split plot arrangement of a randomized complete block design with three replications. The harvest date (Early; 8/3, Medium; 8/15 and late; 8/28) were randomly assigned to whole plots. The cultivars (Tainung-a, Everglade and Whitten) were randomly assigned to subplots. Plots were harvested from the beginning of August through the end of August at approximately 12 day intervals.

2. Chemical analysis

Dry matter (DM) of the sub-samples was determined by drying 100 g of material at 60°C in a forced air oven for 72 h (ASAE Standards, 2003). Dried samples were ground using a Wiley mill (Thomas Scientific, Inc.) to pass through a 1-mm screen and subjected to laboratory tests for forage nutritional value. Dry matter was also determined for ground samples by drying 1 g of sample at 104°C in a forced air oven for 6 h to measure moisture corrections for the fiber fraction analyses. Samples were analyzed to NDF and ADF using an ANKOM fiber analyzer (Ankom Technology Corp., Fairport, NY, USA), and crude protein (CP) using AOAC methods (AOAC 1990).

3. Silage making and analysis

Three cultivars harvested at each growth stage were chopped at a length of cut of 10 mm with a conventional forage cutter. Each crop was ensiled separately the day of cutting in 1.0 L plastic bags at about 500g. Silos were stored for 60 days at room temperature (about 22°C), and fermentation was stopped by freezing the silos to −20°C until the silages were analyzed. A 20 g sample was taken from each silo, diluted 10 fold on a mass basis with distilled water, and macerated for 30 s in a high speed blender. The diluted sample was filtered through 4 layers of cheesecloth, and pH was measured immediately with a pH meter (Model 420). The 20 mL aliquot samples were placed in 50 mL polypropylene centrifuge tubes and was centrifuged for 20 min at 25,100 × g at 4°C, and the supernatant was transferred to a scintillation vial and frozen for later analysis of fermentation products. Fermentation products (i.e., lactic acid, acetic acid, and butyric acid) were determined using high-performance liquid chromatography (HPLC; Muck and Dickerson, 1988). The HPLC system used a refractive index detector (RID-6A, Shimadzu Corp., Kyoto, Japan) and a Bio-Rad Aminex HPX-87H column (Bio-Rad Lab., Hercules, CA, USA) heated to 42°C. The ammonia-N was determined by distillation, using a Buchi 342 apparatus and a Metrohm 655 Dosimat with an E526 titrator according to AOAC (ID 941.04.1990). This is based on the method of Pearson & Muslemuddin (1968) for determining volatile nitrogen (N).

4. Statistical analysis

Data were subjected to analysis of variance using Proc GLM procedure in the Statistical Analysis Systems software package version 9.1 (SAS Institute, Cary, NC, USA). Differences were determined to be significant at $p<0.05$. The interaction effects between the harvesting date and kenaf cultivars also examined but it was not significant. When the treatment effect was significant, means were separated using Fisher's protected the least significant difference (LSD) test.

Ⅲ. RESULTS AND DISCUSSION

The DM yield increased with maturity in all three cultivars, especially Whitten showed the highest DM yield at each harvesting date (Table 1). These results are similar to the DM yield (Everglade: 25 ton ha^{-1} at 115 growing day) observed by Han et al. (2006), but higher than the result (Everglade: 18.2 ton ha^{-1} at 120 growing day) from Webber and Bledoe (2002). The DM yield observed in this study was significantly lower than the result from Najid and Ismawaty (2001). They reported that kenaf could be grown and harvested about four times a year and with a potential annual production of about 40.6 ton DM ha^{-1}. The differences might be contributed from the optimum growth temperate of kenaf which is capable of growing to a height of 6 m on tropical or sub-tropical areas with well-drained fertile soil.

The amount of DM increased ($p<0.05$) as harvest date was delayed (Table 2). The DM

Table 1. Dry matter yield (ton ha^{-1}) of the three kenaf cultivars with different date of harvesting

Harvesting Date	Cultivars			Mean
	Tainung-a	Everglade	Whitten	
Early	20.5	22.4	22.5	21.8
Medium	24.8	24.2	25.1	24.7
Late	26.3	27.1	27.5	27.0

contents of kenaf was lower (DM<200 g kg^{-1}) in early stage of growth but for medium (210-225 g kg^{-1}) and late (212-231 g kg^{-1}) harvesting time met the demands of DM to produce a quality silage (Table 2). However, the DM contents of all cultivars at each harvesting time are still low to make a good quality silage. In order to increase DM content of fresh kenaf for ensiling using additives like beet pulp could be useful. Xiccato et al. (1998) demonstrated that the mixture of chopped kenaf with increasing proportions of dried beet pulp served to both increase silage DM and improved its nutritive value.

The CP contents of the kenaf silage of all three cultivars ranged from 151 to 164 g kg^{-1}. Although the CP contents were not significantly declined with increasing growth stage, the highest value was observed in Whitten at early harvesting date (Table 2). The CP contents observed in this study are much higher than those of the good quality of corn silage. Kenaf silage has merits as a good forage source for high producing cattle such as dairy cows in terms of high protein level compared to corn silage. However, higher forage protein can become more soluble and can be catabolized to non-protein nitrogen (NPN) which is resulted in higher ammonia-N content (Muck, 1987).

Higher contents of NDF and ADF were observed in Everglade at medium and early harvesting time among the treatments, respectively ($p<0.05$). However, the NDF and ADF contents of kenaf in this study were lower than their contents reported by Xiccato et al. (1998). They found the NDF and ADF contents of Everglade are 625 and 472 g kg^{-1} DM at similar growth stage, respectively. Plant maturity is the most important factor affecting forage quality which is associated with the concentrations of NDF and ADF (Pinkerton and Cross, 1992). Usually forage plant maturity changes so rapidly that it is possible to measure significant declines in forage quality. In this study, however, the NDF and ADF contents of all kenaf cultivars did not significantly increase with maturity (Table 2). Little changes of NDF and ADF contents with maturity provide the flexibility to determine the harvesting time which is important for forage quality. Kenaf appeared to shut down plant development when moisture stressed and, suffered leaf loss which is resulted in high contents of NDF and ADF (Muir, 2001).

Lower silage pH was observed in early and medium maturity ($p<0.05$). All treatments produced a pH less than 4.0, which is sufficient for stable storage while the pH was lower in Whitten and Everglade than Tainung-a other at all harvesting date ($p<0.05$). The lower pH in these cultivars may explain by the higher contents of their lactic acids (Table 3). As the amounts of lactic acid increase the silage pH may decrease. These

Table 2. Chemical composition (g kg^{-1} DM) of the silage of the three kenaf cultivars with different date of harvesting

Chemical composition	Date*	Cultivars			Mean
		Tainung-a	Everglade	Whitten	
DM	E	187	192	197	192^{A}
	M	209	213	225	216^{B}
	L	212	211	231	218^{B}
CP	E	151.7	153.9	164.5	156.7
	M	139.6^{a}	150.5^{ab}	154.3^{b}	148.1
	L	149.5	140.3	146.8	145.5
NDF	E	602.5	617.3	582.4	600.7
	M	593.7^{a}	623.2^{b}	592.2^{a}	603.0
	L	613.1	612.2	595.7	607.0
ADF	E	452.1^{ab}	462.5^{b}	435.3^{a}	450.0
	M	443.0	466.1	450.5	453.2
	L	452.2	447.6	442.1	447.3

* Early (E), Medium (M) and Late (L) harvesting time.
^{ab} Rows with different subscripts are different significantly (p<0.05).
^{AB} Columns with different subscripts are different significantly (p<0.05).

results are consistent with findings by Xiccatoet al. (1998), who showed the addition of beet pulp modified the fermentation process slightly by decreasing the pH. No sign of mold were observed and all silages were visually similar. This satisfactory conservation as silage was probably due to the low pH and good glucose-fructose concentration of fresh kenaf resulted in high content of lactic acid in the silage. Differences in pH between treatments can be attributed to the relative levels of the organic acids such as lactic and acetic acids produced as it observed in Table 3. Based on these results, there is an opposite relation of higher content of lactic acid and pH value of silage that could be confirmed by the results of this experiment.

Whitten showed the highest content of lactic acid at the early harvested date than other treatments while acetic acid was higher in early harvested Tainung-a (p<0.05). However, the effect of maturity was not detected in the change of lactic and acetic acid concentrations (p>0.05). In this study, the contents of lactic acid were relatively lower compared to those of corn silage. Lanjit and Kung (2000) found the pH values (3.7-4.2) and lactic acid concentrations (4-7%) of the corn silage with 35-40% DM. Despite the low levels of lactic acid concentration, the lower pH of kenaf silage may be attributed to the relatively high levels of malic acid and polylactic acid in fresh kenaf which provide the sour taste (Kazuko et al., 2004). A good quality silage is achieved when lactic acid is the predominant acid produced. Acetic acid is known as weak organic acid to cause lower pH in the silage while lactic acid has more important role in the preservation of silage. In this study the amounts of lactic acid were similar to those of acetic acid. These results indicate that kenaf silage can increase the aerobic stability. Acetic acid has been proven to be the sole substance responsible for the increased

Table 3. Fermentation characteristics (g kg^{-1} DM) of the silage of three kenaf cultivars with different date of harvesting

Fermentation characteristics	Date*	Cultivars			Mean
		Tainung-a	Everglade	Whitten	
pH	E	3.75[b]	3.50[a]	3.59[a]	3.61[A]
	M	3.92[b]	3.53[a]	3.61[a]	3.69[A]
	L	3.95[b]	3.70[a]	3.75[a]	3.80[B]
Lactic acid	E	20.5[a]	22.5[a]	25.8[b]	22.9
	M	19.8[a]	22.1[ab]	23.5[b]	21.8
	L	19.5[a]	21.9[b]	22.1[b]	21.2
Acetic acid	E	20.2[b]	17.6[a]	16.8[a]	18.2
	M	21.1[b]	18.1[a]	17.1[a]	18.8
	L	20.5[b]	18.5[ab]	17.5[a]	18.8
Butyric acid	E	0.3	0.2	0.2	0.2
	M	0.3	0.2	0.1	0.2
	L	0.2	0.1	0.1	0.1
Ammonia-N (g kg^{-1} total N)	E	108.5	105.1	103.5	105.7
	M	105.3	102.6	102.3	103.4
	L	103.2	103.3	100.1	102.2

* Early (E), Medium (M) and Late (L) harvesting time.
[ab] Rows with different subscripts are different significantly ($p<0.05$).
[AB] Columns with different subscripts are different significantly ($p<0.05$).

aerobic stability, and this acid acts as an inhibitor of spoilage organisms (Danner, et al. 2003).

The low levels of butyric acid concentrations were observed in all cultivars of every harvest date. The high moisture contents of silage often produce lots of butyric acids. D'Urso et al. (1987) and Gaspari (1990) reported the poor suitability for ensiling of the kenaf harvested at earlier stages of growth with high moisture contents (DM<200 g kg^{-1}). A high concentration of butyric acid (>0.5% of DM) indicates that the silage has undergone clostridial fermentation, which is a deteriorating factor of silage quality (Kung and Shaver, 2001). Despite the high moisture contents of the fresh kenaf, the low concentrations of butyric acid in kenaf silage seem to be resulted from the low silage pH of kenaf (Table 3). After harvest of fresh kenaf, however, increasing the DM is necessary for making a good quality silage with little butyric acid concentration.

In this study, the relatively high concentrations of ammonia-N were observed in all cultivars of all growth stage. Ammonia-N in silage has long been associated with reduced silage intake. In part this has arisen because itcan be readily measured, and may act as a simple index of silage fermentation quality. The ammonia-N concentration in silage reflects the degree of protein degradation. Extensive proteolysis adversely affects the utilization of nitrogen by ruminant (Van Vuuren et al., 1999) and may explain due to the high moisture contents of the fresh forage. Proteolysis is a major factor in reducing silage protein utilization and efforts to reduce proteolysis should enhance silage protein utilization. Traditional methods have centered around the reduction of proteolytic activity by either increasing crop DM or by reducing crop pH or through a combination of both. Muck (1987) found that wilting markedly reduces proteolysis by plant enzymes in the silo. The kenaf silage showed the ammonia-N concentration of above 100 g kg^{-1} total N in all cultivars (Table 3) which is relatively higher in compared to the high quality of corn silage or whole crop rice silage (Kim et al., 2004). However, no difference of ammonia-N content was observed among three cultivars with three different growth stage even though the greatest difference was shown between Whitten harvested at late stage (100.1 g kg^{-1} total N) and Tainung-a harvested at early stage (108.5 g kg^{-1} total N).

Ⅳ. CONCLUSIONS

In this study, kenaf showed promise as a forage silage in Korean environment. All variables studied in this experiment had some effects on the nutritive value and fermentation quality of kenaf silage. Among the three cultivars studied, Whitten harvested at late growing stage showed the greatest results for producing high-quality silage under Koran environments. The lower levels of silage pH can help the kenaf forage ferment well and result in a stable silage. However, the higher moisture content of kenaf often makes the ensiling of the forage difficult. We suggest using additives like beet pulp to increase DM contents of fresh kenaf in order to make the silage easier with better quality.

Ⅴ. ACKNOWLEDGEMENT

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