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Yunus, Muhammad

Laboratory of Animal Feed Science, Division of Animal Science, Department of Animal and Marine Bioresource Science, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University

Ohba, Noriko

Research Student under the Supervision of Professor Yasuhisa Masuda, School of Agriculture, Kyushu University

Shao, Tao

Laboratory of Animal Feed Science, Division of Animal Science, Department of Animal and Marine Bioresource Science, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University

Yano, Yasukatsu

Laboratory of Animal Feed Science, Division of Animal Science, Department of Animal and Marine Bioresource Science, Faculty of Agriculture, Kyushu University

他

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Effect of Ensiling Density on Fermentation Quality of Napiergrass (*Pennisetum purpureum* Schumach.) Silage

Muhammad Yunus*, Noriko Ohba, Tao Shao*, Yasukatsu Yano,
Manabu Tobisa, Masataka Shimojo and Yasuhisa Masuda*****

Laboratory of Animal Feed Science, Division of Animal Science, Department of Animal
and Marine Bioresource Science, Faculty of Agriculture,
Kyushu University, Fukuoka 812–8581

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The poor quality of silage of tropical grasses may related to the difficulty of excluding air at ensiling due to their high fiber content. The processes of respiration and proteolysis by plant enzymes during the early stages of ensiling are very important keys to make good quality silage. The aim of this experiment is to clarify whether the exclusion of air from the silage mass affects the quality of the napiergrass silage. Two plots of napiergrass were cultivated: one was applied with nitrogen (N) at 50 kg/ha in April and the other was not applied with N. The first growth was harvested in July and immediately chopped into about 1 cm length. The treatments were high (77 g/100 ml), medium (63 g/100 ml) and low (49 g/100 ml) densities of ensiling. Napiergrass was ensiled into a laboratory silo and incubated for 6, 15 and 30 days at 25 °C. After opening the silo, pH, total nitrogen (TN), volatile basic nitrogen (VBN) and organic acids were determined. No significant effects of N application were observed in all parameters tested except for N content of silage. The pH value, acetic acid, butyric acid, VBN/TN significantly ($P < 0.01$) decreased in the high density silage, while lactic acid increased. The pH value was increased by low density ensiling due to higher VBN/TN. In conclusion, high density ensiling into the silo could improve the fermentation and nutritive qualities of napiergrass silage irrespective of application.

INTRODUCTION

The low content of sugar is the main problem for tropical grass silage making, especially napiergrass (*Pennisetum purpureum* Schumach.) silage. Application of nitrogen (N) fertilizer increases the concentration of leaf protein, but in contrast reduces the concentration of fermentable carbohydrate (McDonald *et al.*, 1995).

In silage making with tropical grasses of low sugar content, the processes of respiration and proteolysis by plant enzymes after cutting and during the early stages of ensiling play important key roles in determining the quality of silage.

The respiration process of plant materials involves the oxidation of plant sugar with the release of carbon dioxide, water and energy. Respiration will continue while both oxygen and plant sugars remain in the silo (McDonald *et al.*, 1991). Thus, the volume of

* Laboratory of Animal Feed Science, Division of Animal Science, Department of Animal and Marine Bioresource Science, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University

** Research Student under the Supervision of Professor Yasuhisa Masuda, School of Agriculture, Kyushu University

*** Corresponding author (E-mail: ymasuda@agr.kyushu-u.ac.jp)

air sealed in a silo affects the duration of respiration and consequently the loss of sugars. The ways of consolidation and sealing determine the amounts of air penetrating the silage mass. In the present study, therefore, the effects of density of forage materials in the silo on the quality of silage were examined with napiergrass grown under different N application and ensiled with low, medium and high densities.

MATERIALS AND METHODS

For silage preparation, two plots of napiergrasses were cultivated in the field of Kyushu University, Hakozaki, Fukuoka, Japan. One of these plots was given N fertilizer (+) at 50 kg/ha in April 1998. No application of N (-) was done for the other plot. The initial growth of both plots was harvested at about 15 cm above the ground using a hand sickle in July 1998. The plants were immediately chopped into about 1 cm length using an electric chopper. The plant materials were ensiled into the laboratory silo (100 ml polyethylene container) with the density of 77 g fresh weight/100 ml (high density; H), 63 g fresh weight/100 ml (medium density; M) or 49 g fresh weight/100 ml (low density; L) and incubated for 6, 15 or 30 days at room temperature (25 °C). The treatments were 2 (with or without N fertilizer) × 3 (high, medium or low ensiling density). Three replicates were prepared for each treatment.

After opening the silo, dry matter (DM) content in silage was determined by drying in an oven at 60 °C for at least 48 h (AOAC, 1984) and corrected with the content of volatile components. Sixty grams of sample were soaked in 120 ml of water and stored at 4 °C for 1 day. The filtrates were used for the determination of pH, volatile basic nitrogen, lactic acid and volatile fatty acids.

The pH of silage was measured by a glass electrode pH meter (Horiba Co.). The total nitrogen was analyzed by the Kjeldahl method and the volatile basic nitrogen (VBN) by the steam distillation method. The determination was made for lactic acid (LA) by the method of Barker and Summerson (1941), and for acetic acid (AA) and butyric acid (BA) by gas chromatography (Shimadzu GC-17A with 12 m capillary column, condition: column temperature 100 °C, injection temperature 250 °C and detection temperature 250 °C).

The data were analyzed statistically by three-way analysis of variance.

RESULTS

The pH value and DM content of silages are shown in Fig. 1. High density significantly decreased pH value at 6 and 15 days of storage compared with low density. There was a significant interaction between the level of density and the days of storage for pH. The Low density showed significantly higher pH value than high density after 6 and 15 days of storage, but no significant effect of density was observed after 30 days. The highest pH value was found in the low density after 6 days, but its pH gradually decreased until 30 days. High density of ensiling tended to slightly increase DM content of silage.

As shown in Fig. 2, the application of N at the rate of 50 kg/ha significantly ($P < 0.05$) increased TN, but there were inconsistent effects on VBN/TN in the silage. A significant ($P < 0.05$) interaction was observed between N application and the level of density. In the high density N application increased VBN/TN after 6 days but decreased it on 15 and 30

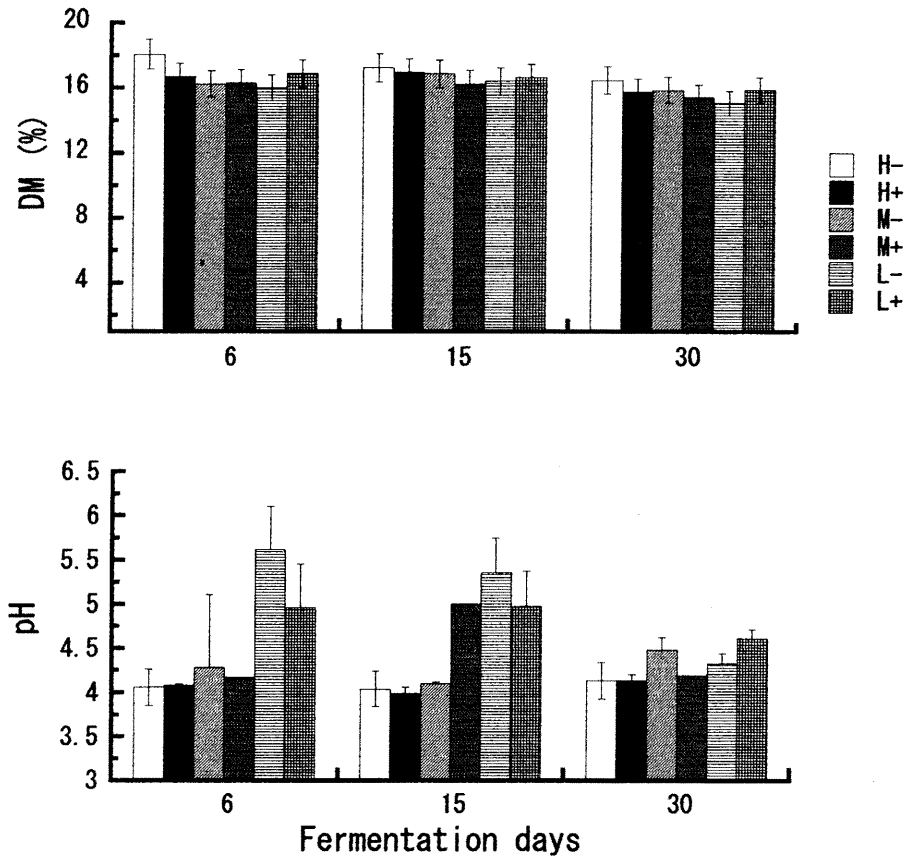


Fig. 1. The effects of ensiling density, nitrogen (N) application and days after ensiling on pH value and dry matter (DM) content of napiergrass silage. Values are mean \pm SD (three replicates). H=High density, M=Medium density, L=Low density, +=nitrogen application and -=without nitrogen application. The results of ANOVA (significant effects) were: (1) density ($P < 0.01$) and interaction [density \times days ($P < 0.05$)] for pH value, (2) density ($P < 0.05$), days ($P < 0.01$) and interaction [N \times days ($P < 0.05$)] for DM.

days, whereas N application increased it after 15 days in the medium density and after 30 days in the low density. The VBN/TN showed higher values in the low density than in the other two densities.

Fig. 3 shows LA, AA and BA contents in the silages. Highest LA production was found in the high density. The LA content in the medium and high density silages were significantly ($P < 0.01$) higher than that of the low density. At all densities, days of storage from 6 to 30 days did not show different effects on LA production. The AA content of the low density silage was significantly ($P < 0.01$) higher than that of the medium and high density silages. The BA was not detected in the high density silage. In the

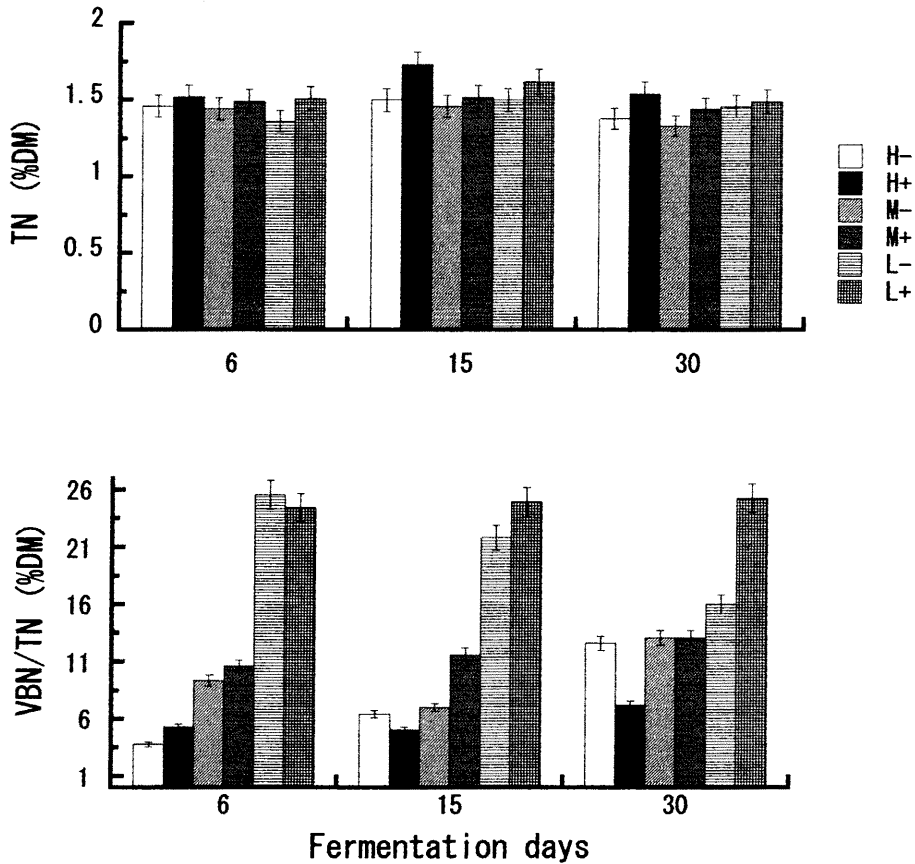


Fig. 2. The effects of ensiling density, nitrogen (N) application and days after ensiling on total nitrogen (TN) and the ratio of volatile basic nitrogen (VBN) to TN (VBN/TN) of napiergrass silage. Values are mean \pm SD (three replicates). H=High density, M=Medium density, L=Low density, +=nitrogen application and -=without nitrogen application. The results of ANOVA (significant effects) were; (1) density ($P < 0.05$), N ($P < 0.01$) and days ($P < 0.01$) for TN, (2) density ($P < 0.01$), interaction [density \times N ($P < 0.05$), density \times days ($P < 0.05$)] for VBN/TN.

medium density BA production without N application was detected after 6, 15 and 30 days of storage, whereas with N application BA production was detected after 15 days only. In the low density BA production was detected after 6 and 15 days irrespective of N application.

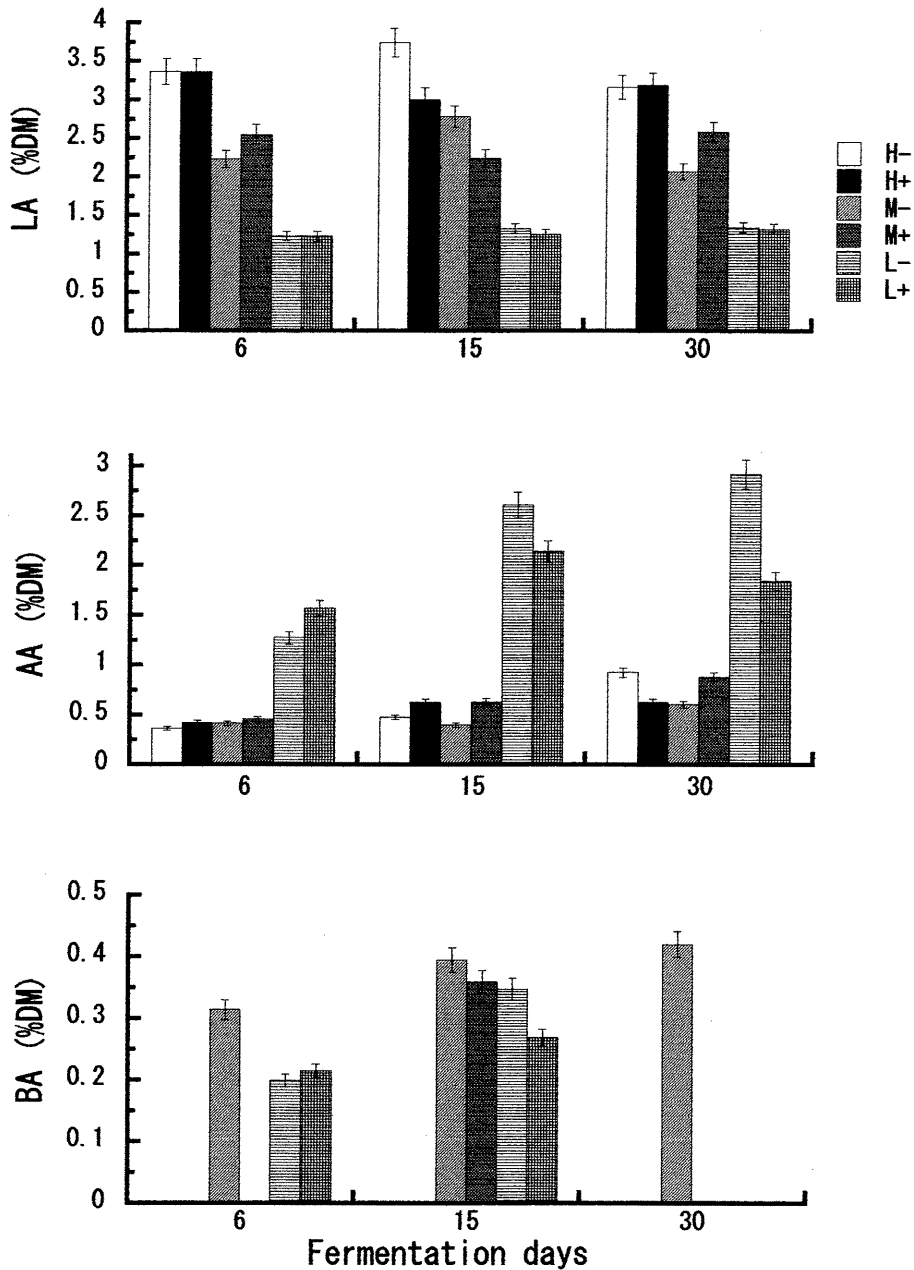


Fig. 3. The effects of ensiling density, nitrogen (N) application and days after ensiling on lactic acid (LA), acetic acid (AA) and butyric acid (BA) contents of napiergrass silage. Values are mean \pm SD (three replicates). H=High density, M=Medium density, L=Low density, +=nitrogen application and -=without nitrogen application. The results of ANOVA (significant effects) were: (1) density ($P < 0.01$) for LA, (2) density ($P < 0.01$) and days ($P < 0.05$) for AA, (3) density ($P < 0.05$) and days ($P < 0.05$) for BA.

DISCUSSION

Woodard *et al.* (1991) reported that mean pH value of napiergrass silages made from the plant harvested with different cutting frequencies showed 3.8 to 4.0. Thus, the value obtained in the present study for the high density may be valid. Higher density of storage resulted in high fermentation quality of napiergrass silage, where the pH value of 4.10 was rapidly achieved by the higher LA production from 6 days and being maintained until 30 days. However, the low density of storage caused the low fermentation quality of silage with higher VBN/TN and BA production.

There was an opposite result between high and low densities in LA and AA contents. The high level of density increased LA and decreased AA contents, but the reverse was true for the low density. The rapid and higher production of AA may be a result of higher proliferation of aerobic bacteria in the low density silage in which aerobic phase persisted longer.

It is clear that oxygen in the silo plays a very important role to determine the fermentation quality (Scudamore and Livesey, 1998). Two important plant enzyme activities in plant tissues, respiration and proteolysis, which occur during aerobic phase (early days of fermentation), are recognized: respiration breakdowns plant sugars to carbon dioxide and water using oxygen and releasing heat, and proteases degrade protein to amino acids and ammonia (McDonald *et al.*, 1991). Loss of sugars during this phase is crucial from the point of silage preservation especially for tropical grasses including napiergrass, because of the shortage of substrate for LA bacteria.

At the low density silage the higher level of oxygen and longer aerobic condition might exist in the silo, resulting in the continuing of metabolism of plant cells and activity of enzymes in plant tissues during the early stage of fermentation. This phenomenon and aerobic microbial development caused the large loss of soluble carbohydrates for LA bacteria fermentation, and in consequence, lowered LA production and increased pH value due to secondary fermentation, and then the release of ammonia occurred in the silage, as reported by Ruxton *et al.* (1975). Catchpoole and Henzell (1971) reported that silages made from a number of tropical grass species have been low quality with high pH value in the consequence of lower LA bacteria fermentation. One of the reasons of this low quality may come from the difficulty in exclusion of air due to the high fiber content of tropical grasses.

Because of higher loss of sugar and enhancement of proteolysis in the low density during the first stage of storage, pH value was not lowered less than 4.6. This point did not depress clostridial activity (Bolsen *et al.*, 1996; McDonald *et al.*, 1991).

Application of N on planted grasses caused increases in TN content in the silage (Jacobs *et al.*, 1998). However, McDonald *et al.* (1991) reported that high level of N fertilizer caused a reduction in fermentable carbohydrates and an increment in protein content and consequently resulted in a high pH value in the silage. In the present experiment application of N fertilizer at the rate of 50 kg/ha on planted napiergrass increased TN content in the silage, but did not affect other parameters.

Based from those results of the present experiment, we can conclude that (1) rapid exclusion of air from silos to maintain anaerobic condition throughout the storage period is essential if the quality of napiergrass is to be improved and maintained, (2) ensiling

napiergrass with high density in the silo can make good quality silage even under the N application in the field.

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