



Article

# Fermentation Quality of Round-Bale Silage as Affected by Additives and Ensiling Seasons in Dwarf Napiergrass (*Pennisetum purpureum* Schumach)

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**Abstract:** Fermentation quality of dwarf napiergrass (*Pennisetum purpureum* Schumach) was estimated for additives lactic acid bacteria and *Acremonium* cellulase (LAB + AC), fermented juice of epiphytic lactic acid bacteria (FJLB), and a no-additive control in 2006 via two ensiling methods—round-bale and vinyl-bag methods in 2006—and via two ensiling seasons—summer and autumn of 2013. Fermentation quality of dwarf napiergrass ensiled in the summer season was improved by the input of additives, with the highest quality in LAB + AC, followed by FJLB; the lactic acid content was higher, and the pH and sum of the butyric, caproic, and valeric acid contents were lower, resulting in an increase in the V-score value by each additive. The ensiling method in autumn without additives affected fermentation quality, mainly due to the airtightness, which was higher for round-bale processing than in vinyl bags, even with the satisfactory V-score of 72. Fermentation in round bales without additives had a higher quality in autumn than in summer, possibly due to the higher concentration of mono- and oligo-saccharides. Thus, it was concluded that dwarf napiergrass can be produced to satisfactory-quality silage by adding LAB + AC or FJLB in summer and even in the absence of additives in autumn.

**Keywords:** silage processing; lactic acid bacteria; fermentation quality; dwarf napiergrass

## 1. Introduction

Superior properties of a dwarf variety of late-heading type napiergrass (*Pennisetum purpureum* Schumach) were verified in our previous research, such as a high winter survival for several years [1] and a high palatability of silage compared with sorghum or Sudangrass [1], and a satisfactorily high total digestible nutrient (TDN) concentration of silage of 552–593 mg/g in two digestion trials with Japanese Black breeding cows [1]. Therefore, dwarf napiergrass can be utilized as a perennial without reestablishment every spring in Northern Kyushu, Japan, and is a promising forage for beef cow-calf-producing farmers in the region [1]. Dwarf napiergrass shows high winter survival imposed by the mid to late November closing cut in the region and even on remote islands [2].

Since dwarf napiergrass is highly ranked in nutritive value among tropical grasses, the silage produced from the crop is available for preserved roughage in a winter season. The fermentation quality of round-bale silage of dwarf napiergrass was evaluated as unstable due to low water-soluble carbohydrates, compared with other tropical grasses, which remains to be solved for sustaining the long-term quality of the silage. The silage produced from normal-type napiergrass produced lactic acid

as a primary fermentation product [3,4], especially when the addition of a saccharide such as glucose was added during fermentation [5,6]. Normal-type napiergrass ensiled with corn [7], molasses [8–11], formic acid [6], and ethanol [12] as additives would produce good-quality lactic-type silage.

A harvester or round-baler equipped with instruments can produce round-bale silage with added additives simultaneously. Lactic acid bacteria are easier to add to ensiling round-bale silage than citrus pulp, wheat bran, or beet pulp. Since the addition of the fermented juice of epiphytic lactic acid bacteria (FJLB) to grasses improves the fermentation quality of silage [5,13–15], this technique should apply to the ensiling of dwarf napiergrass.

The fermentation quality of dwarf napiergrass silage may be affected by the method of ensilage or the ensiling season. Small-scaled beef cow-calf-producing farmers in the region usually have no round-baler, since they process vinyl-bag silage as storage herbage. The ensilage of dwarf napiergrass can be carried out in summer and autumn, when the storage temperature of silages is different and may affect the fermentation quality of the silages.

This study was aimed primarily to determine the effect of several additives on fermentation quality in round-bale processed dwarf napiergrass silage, secondarily to determine the fermentation quality of dwarf napiergrass ensiled without additives by comparing round-bale and vinyl-bag silages, and thirdly to determine the effect of the ensiling season on the fermentation quality of dwarf napiergrass silage.

## 2. Results

### 2.1. Growth Characteristics and Nutritive Values of Dwarf Napiergrass

Table 1 shows regrowth days, plant length, dry matter (DM) yield, the ratio of leaf blade (LB) to stem with leaf sheath (ST), abbreviated as LB/ST, and the moisture concentration of dwarf napiergrass upon ensiling in early September (summer season) and late November (autumn season). Regrowth days and plant length at ensiling ranged from 78 to 104 days and from 85.3 to 152.7 cm, respectively. The DM yield tended to increase and LB/ST tended to decrease with increases in plant length. The moisture concentration of plant samples ranged from 81.7% to 86.5% irrespective of plant length and ensiling season, demonstrating that each plant sample was ensiled at high moisture without wilting. Crude protein (CP) concentration and IVDMD at the ensiling of dwarf napiergrass ranged from 90 to 133 mg/g and 59.1% to 72.1%, respectively (Table 2).

**Table 1.** Regrowth days, Plant length, dry matter (DM) yield, ratio of leaf blade to stem with leaf sheath (LB/ST) and moisture concentration at ensiling of dwarf napiergrass (Experiments 1–3).

Experiment (Exp.)	Target for Trial	Year from Establishment	Ensiling Date	Time of Cut	Regrowth Days (Days)	Plant Length (cm)	DM Yield (Mg/ha)	LB/ST	Moisture (%)
Exp. 1	Additives	First	4 September 2006	1st	97	126.5	5579	1.99	86.5
Exp. 2	Ensiling method	First	21 November 2006	2nd	78	85.3	2197	3.08	81.7
Exp. 3	Ensiling season	Second	5 September 2011	1st	104	152.7	12258	1.04	84.5
			28 November 2011	2nd	84	120.2	7497	1.67	86.2

**Table 2.** Crude protein (CP) concentration and in vitro dry matter digestibility (IVDMD) at ensiling of dwarf Napiergrass (Experiments 1–3).

Experiment (Exp.)	Target for Trial	CP (mg·g DM <sup>-1</sup> )	IVDMD (%)
Exp. 1	Additives	93	72.1
Exp. 2	Ensiling method	90	68.2
Exp. 3	Ensiling season	117	59.1
		133	67.9

### 2.2. Fermentation Quality in the Additives Trial (Experiment 1)

The organic acid components and fermentation quality of dwarf napiergrass silages in Experiment 1 are shown in Table 3. Though the proportion of lactic acid was highest of the organic acid components in the control, acetic and propionic acids, and n-butyric or higher acids were significantly greater than in other silages. Therefore, the control was estimated as 45 by V-score due to high acetic, propionic, and n-butyric or higher acid compositions, indicating poor quality based on calculations [16].

**Table 3.** Organic acids and fermentation quality in round-bale silages of dwarf Napiergrass ensiled in summer season (Experiment 1).

Trial	Plot <sup>1</sup>	Organic Acid Composition			Fermentation Quality		
		Lactic (% FM)	C2 + C3 <sup>2</sup> (% FM)	C4 + C5 + C6 <sup>3</sup> (% FM)	VBN/TN <sup>4</sup> (%)	V-Score <sup>5</sup>	pH
Additives	LAB + AC	2.40 <sup>a,6</sup>	0.245 <sup>b</sup>	– <sup>7</sup>	7.19 <sup>b</sup>	95	3.59 <sup>d</sup>
	FJLB	2.16 <sup>a</sup>	0.323 <sup>b</sup>	– <sup>6</sup>	16.9 <sup>a</sup>	62	3.73 <sup>c</sup>
	Control	0.69 <sup>b</sup>	0.638 <sup>a</sup>	0.252 <sup>a</sup>	15.4 <sup>ab</sup>	45	4.46 <sup>a</sup>

<sup>1</sup> FJLB: Fermented juice lactic acid bacteria, LAB: Lactic acid bacteria, LAB + AC: LAB + *Acromonium* cellulase, Control: No-additives; <sup>2</sup> Sum of acetic and propionic acids; <sup>3</sup> Sum of butyric, caproic and valeric acids containing each isomer; <sup>4</sup> Ratio of volatile basic nitrogen to total nitrogen; <sup>5</sup> V-score indicates fermentation quality of silages with judging by the score of good (above 80), fair (60–80) and poor (below 60); <sup>6</sup> The values with different small letter within the same column are significantly different at 5% level; <sup>7</sup> Not detected.

On the other hand, the fermentation quality estimated by the V-score of the FJLB and lactic acid bacteria and *Acromonium* cellulase (LAB + AC) treatments was identified as good and fair, respectively, due to a higher lactic acid, lower acetic and propionic acid concentrations in FJLB and LAB + AC than the control, and no detection of n-butyric or higher organic acids. It is a common feature that the ensilage of tropical grasses with high moisture content leads to poor fermentation due to little production of lactic acid. In the present study, however, lactic acid production was detected even in the control without inoculants.

### 2.3. Ensiling Method Trial (Experiment 2)

The organic acid components and fermentation quality of dwarf napiergrass silages in Experiment 2 are shown in Table 4. Although the concentration of lactic acid was the highest of the organic acid components in the silage of each ensiling method, the lactic acid concentration was significantly higher and the pH value significantly lower in round-bale silage than in vinyl-bag silage. Therefore, the fermentation quality estimated in round-bale silage was estimated to have a V-score of 85, identified as good due to the absence of n-butyric or higher organic acid detection, in contrast with the V-score of 72 in vinyl-bag silage, due to little detection of butyric or higher organic acids, identified as fair.

**Table 4.** Organic acids and fermentation quality in silages of dwarf Napiergrass ensiled in autumn season (Experiment 2).

Trial	Plot	Organic Acid Composition			Fermentation Quality		
		Lactic (% FM)	C2 + C3 <sup>1</sup> (% FM)	C4 + C5 + C6 <sup>2</sup> (% FM)	VBN/TN <sup>3</sup> (%)	V-Score <sup>4</sup>	pH
Ensiling method	Round bale	1.916 <sup>a,5</sup>	0.323	– <sup>6</sup>	11.0	85	4.02 <sup>b</sup>
	Vinyl bag	0.764 <sup>b</sup>	0.555	0.070	12.6	72	4.35 <sup>a</sup>

<sup>1</sup> Sum of acetic and propionic acids; <sup>2</sup> Sum of butyric, caproic and valeric acids containing each isomer; <sup>3</sup> Ratio of volatile basic nitrogen to total nitrogen; <sup>4</sup> V-score indicates fermentation quality of silages with judging by the score of good (above 80), fair (60-80) and poor (below 60); <sup>5</sup> The values with different small letter within the same column are significantly different at 5% level; <sup>6</sup> Not detected.

#### 2.4. Ensiling Season Trial (Experiment 3)

The organic acid components, fermentation quality, and the mono- and oligo-saccharide concentrations of dwarf napiergrass silages in Experiment 3 are shown in Table 4. The buffering capacity of the plants at ensiling was significantly higher at 35.6 g/kg DM in the autumn silage than at 30.9 g/kg DM in the summer silage. The mono- and oligo-saccharide concentrations of the plant samples were also significantly higher at 4.58% DM in the autumn silage than at 1.83% DM in the summer silage. Irrespective of ensiling season (summer or autumn), the silage in each plot produced lactic acid at the highest percentage of all organic acids. The acetic and propionic acid proportion of silage ensiled in the summer was significantly higher than in autumn, and n-butyric or higher organic acids were detected only on slight levels in the summer silage. The fermentation quality based on the V2-score was estimated at 100 in the autumn silage and identified as good, compared with the V2-score of 61 in the summer silage identified as fair.

### 3. Discussion

Based on the results of the additive trial (Experiment 1), an addition of LAB + AC apparently improved fermentation quality of ensiled napiergrass. In contrast, no positive effects of additives on normal napiergrass ensilage were reported by Uchida and Kitamura [17]. It is a common observation that the positive effect of LAB on the fermentation of grass silage depends on the type of bacteria [18,19], so the choice of LAB should fit the grass being examined. The fermentation quality of silage added with FJLB was better than that without additives, which is consistent with past research findings about normal napiergrass ensilage [5,14]. The fermentation quality of LAB + AC was the highest across present additives and improved due to the addition of cellulase in the summer season, when the grass had lower mono- and oligo-saccharide concentrations. The present results correspond fairly well with a previous study finding, which showed remarkable improvement in fermentation quality following cellulase additions [20]. Tagawa et al. [21] reported that cellulose concentration of reed canarygrass (*Phalaris arundinacea*) silage, by adding 0.5% fresh matter of LAB + AC, the same as the present research condition, was significantly lower than that ensiling without additives. The addition of enzyme alone or combined with inoculants at ensiling aimed to increase available substrates and improve lactic acid fermentation in silages [22]. Structural fiber components such as cellulose, neutral detergent fiber (NDF), or acid detergent fiber (ADF) in silage were not determined in the present study. However, it was considered that the fermentation quality of silages was improved by the addition of LAB + AC, which should degrade the cellulose of napiergrass.

In the study of seasonal ensiling effects (Experiment 3), the concentration of organic acids other than lactic acid was lower in the autumn ensilage than in the summer ensilage when producing without additives, which was beneficial for achieving a lower pH and higher V-score. Processing round-bale dwarf napiergrass silage without additives in the autumn, as shown in Table 5, proved to be reliable for obtaining similarly good fermentation quality. In Okinawa Prefecture, when the growth of normal napiergrass is retarded in the growing season from autumn to winter, the

fermentation quality of normal napiergrass silage without additives is reportedly lower in the material harvested in winter than in summer, and the fermentation quality is strongly promoted by the total nonstructural carbohydrate concentration [23]. In the present study, although the buffering capacity of plant samples was higher in the autumn than in the summer plant samples, the mono- and oligo-saccharide concentration of the grass was higher in autumn than in summer, as shown in Table 5, and the concentration of these saccharides is considered to improve fermentation quality. Kobayashi and Nishimura [24] demonstrated that several tropical grasses that preserved a total nonstructural carbohydrate concentration higher than 10% DM showed superior over-wintering ability by suppressing growth. The water-soluble carbohydrate concentration of dwarf napiergrass grown under low temperatures (15 °C) was higher than that at high temperatures (35 °C) [25]. This allows the conclusion that ensiling napiergrass before the winter season, when the air temperature is decreasing, leads to the accumulation of mono- and oligo-saccharides. In addition, ensilage in the summer was preserved under higher temperatures than in the autumn. Ensiling grass material at high moisture facilitates the production of butyric acid by fermentation, implying that the population of *Clostridium* bacteria would also increase in silage, with an increase in the ensiling temperature. Therefore, preserving silages under a higher air temperature is also considered to deteriorate fermentation quality. Woodard et al. [26,27] and Fukagawa et al. [2] demonstrated the consistent fermentation quality of dwarf napiergrass silage, which also leads to a favorable fermentation quality when the growth stage is extended. As shown for Experiment 2, the fermentation of dwarf napiergrass round-bale silage demonstrated good quality due to its high percentage of lactic acid concentration and high V-score when ensiled in autumn (Table 4), even though the plant length then was the lowest of the studied materials (Table 1). The present results suggest that fermentation quality can be greatly affected not only by the growth stage but also by the ensiling season, for example in autumn, when the grass accumulates mono- and oligo-saccharides or water-soluble carbohydrates.

**Table 5.** Mono- and oligo-saccharide concentration and buffering capacity at ensiling, organic acids and fermentation quality in round-bale silages of dwarf Napiergrass ensiled in summer and autumn seasons (Experiment 3).

Season and Date at Ensiling	Mono- and Oligo-Saccharide Concentration (DM %)	Buffering Capacity (g/kg DM)	Organic Acid Composition			Fermentation Quality	
			Lactic (% FM)	C2 + C3 <sup>1</sup> (% FM)	C4 + C5 + C6 <sup>2</sup> (% FM)	V2-Score <sup>3</sup>	pH
Summer (5 September)	1.80 <sup>b,4</sup>	30.9 <sup>b</sup>	0.886	0.663 <sup>a</sup>	0.225	61 <sup>b</sup>	4.90 <sup>a</sup>
Autumn (28 November)	4.58 <sup>a</sup>	35.6 <sup>a</sup>	0.819	0.142 <sup>b</sup>	– <sup>5</sup>	100 <sup>a</sup>	4.44 <sup>b</sup>

<sup>1</sup> Sum of acetic and propionic acids; <sup>2</sup> Sum of butyric, caproic and valeric acids containing each isomer; <sup>3</sup> V2-score indicates fermentation quality of silages with judging by the score of good (above 80), fair (60-80) and poor (below 60); <sup>4</sup> The values with different small letter within the same column on each experiment are significantly different at 5% level; <sup>5</sup> Not detected.

In Experiment 2, which assessed the effect of the ensiling method, the fermentation in vinyl-bag silage harvested by the flail-type harvester tended to have lower quality than round-bale silage harvested by the combination baler. The lactic acid concentration in tropical grass silages tended to increase with decreasing chopping length [8,28], and the rate of silage intake by dairy heifers tended to increase [8]. However, the difference in fermentation quality between the two ensiling methods was not due to the difference in chopping length, because the same flail-type harvester was applied in both ensiling methods. Round-bale silage wrapped with twine and film was produced at a higher density than vinyl-bag silage, and its airtightness was considered to improve fermentation quality. The present study on napiergrass silage processing corresponds to that on Guineagrass silage, where the silage preserved at a higher density showed better fermentation quality than lower-density silage [29]. Even vinyl-bag silage without additives that was harvested by a flail-type harvester in autumn had a satisfactory quality, which may be exploited by smallholder cow-calf-producing farmers in the region as winter-stored forage.

Even though a moderate moisture concentration for silage processing ranges from 65% to 72% in napiergrass [26,27], silage processing in the present study was performed under a high moisture concentration of around 85%. High-moisture silage produces a high level of effluent, which results in nutrient loss [20,30] or an increase in *Clostridium* bacteria. Such high-moisture grass material should be ensiled with the addition of LAB + AC or FJLB to effectively increase the silage fermentation quality. The fermentation quality of silage does not always correlate with its intake rate, since dry matter intake and the palatability of dwarf napiergrass silage for Japanese Black breeding cows were higher than that of Sudangrass silage processed by a round-baler, even though the fermentation quality of dwarf napiergrass silage without additives in the summer was apparently lower than that of the Sudangrass silage [1]. Since obtaining a good fermentation quality for long-term preservation is regarded as a more important trait than a high intake rate, the input of several LAB additives to round-bale silage could be a good solution to addressing these problems.

#### 4. Materials and Methods

##### 4.1. Experimental Design, Pasture Management, and Growth Measurements

The napiergrass (*Pennisetum purpureum* Schumach) genotype examined was a dwarf variety of a late-heading type [31,32], designated as “dwarf napiergrass.” Three separate experiments for fermentation quality of dwarf napiergrass silages were conducted at the Livestock Research Division, Nagasaki Agricultural and Forestry Technical Development Center in Shimabara, Nagasaki (32°14' N, 130°20' E). A dwarf napiergrass pasture (500 m<sup>2</sup>) per replication was established in three replications under a completely randomized design with planting rooted tillers at 2 plants/m<sup>2</sup> with a 1 m inter-row and a 0.5 m intra-row spacing on 30 May 2006 for Experiment 1 (additives trial at three levels) and Experiment 2 (ensiling method trial at three levels), and separately on 24 May 2013 for Experiment 3 (ensiling season trial at two levels).

Pastures were supplied with manure mixed with cattle, swine, and poultry waste at 2000 g/m<sup>2</sup> in both 2006 and 2013, with a respective N concentration of 0.54% dry matter (DM) and 0.65% DM, respectively, and a moisture content of 66.6% and 62.0%, respectively. Soil amendments were also supplied at 100 g/m<sup>2</sup> calcium-magnesium phosphate and 6 g/m<sup>2</sup> fused magnesium phosphate (containing 20% P<sub>2</sub>O<sub>5</sub>) in both 2006 and 2013.

In Experiments 1 and 2, chemical compound fertilizer with 10 g/m<sup>2</sup> of both N and K<sub>2</sub>O was top-dressed a week after planting. In Experiment 1, plant materials were collected at the first cutting on 4 September 2006. In Experiment 2, the chemical compound fertilizer was top-dressed again after the first cutting in Experiment 1, and plant materials were collected at the second cutting on 21 November 2006.

In Experiment 3, 5 g/m<sup>2</sup> of both N and K<sub>2</sub>O were top-dressed a week after planting on 24 May 1993; the second top-dressing a month after planting. The third top-dressing after the first cutting on 11 August 1993 was 10 g/m<sup>2</sup> of both N and K<sub>2</sub>O.

The plant growth of dwarf napiergrass was measured as plant length at harvest in each experiment, and plant samples cut at 10 cm above the ground surface were divided into leaf blade, stem (inclusive of leaf sheath), and dead parts. The DM weight of each plant part was determined after oven drying at 70 °C for 72 h.

The CP concentration and in vitro DM digestibility (IVDMD) of the samples were analyzed with a Kjeltex analyzer (FOSS, Hillerød, Denmark) and pepsin-cellulase assay [33].

##### 4.2. Additives Trial (Experiment 1)

First-cut dwarf napiergrass in the summer season was harvested on 4 September 2006 by a flail type harvester equipped with a round-baler (JCB1420 Combination Baler, Ihi Star Co. Ltd., Sapporo, Japan) and ensiled with several additives using a polyethylene film (BaleWrap, MSK Farm Machinery Corporation, Eniwa, Japan) and wrapping bales by six layers. The additives, added at

1% fresh matter weight, was a formulation of commercial lactic acid bacteria, *Lactobacillus rhamnosus* (Snow Lact L. Acremo, Snow Brand Seed Co. Ltd, Sapporo, Japan), which includes cellulase from *Acremonium cellulolyticus* and *Trichoderma viride* (Activity of avicelase: over than 924 U/g, measured at 1% Avicel of the substrate, pH 4.5 and 50 °C), abbreviated as LAB + AC, and ensiling without additives was set as a control. LAB + AC (350 g) was prepared from the commercial additives diluted in 10 L tap water. FJLB was prepared from 1 kg fresh dwarf napiergrass, chopped with a hand cutter into 3 to 5 cm lengths, put into 20 L tap water containing 1 kg sucrose in the liquid, and kept under anaerobic conditions in a glasshouse for 2 days. The fermentation quality of round-bale silage was examined 7 months after ensiling.

#### 4.3. Eniling Method Trial (Experiment 2)

The second-cut dwarf napiergrass in the autumn season was harvested on 21 November 2006 by two types of machinery, a flail-type harvester equipped with a round-baler, which were the same as in Experiment 1, and a flail-type harvester (Taarup DM1100, Kverneland AS, Oslo, Kingdom of Norway) only, and was ensiled without additives into round-bale silage and vinyl-bag silage, respectively. The vinyl-bag silage consisted of 20 kg of fresh material and was stocked in a 50 L vinyl bag (72 cm diameter, 135 cm height, and 0.1 mm thickness), which was placed under vacuum to establish anaerobic conditions by a vacuum cleaner and sealed. The fermentation quality of the silages was examined 5 months after ensiling.

#### 4.4. Ensiling Season Trial (Experiment 3)

Dwarf napiergrass was harvested with a flail-type harvester equipped with a round-baler in the summer season for the first-cut plants on 5 September 2013 and in the autumn season for the second-cut plants on 28 November 2013, and ensiled without additives. The fermentation quality of the silages was examined 2 months after ensiling.

Dry samples of each plant part (leaf blade, stem and dead parts) were milled through a 1 mm sieve by a grinder mill, and 80% ethanol extracts obtained by shaking plant samples at 40 °C for 16 h were analyzed for concentrations of mono- and oligo-saccharides using an HPLC (detector: Refractive Index Detector, RI-2031 Plus, JASCO Corporation, Tokyo, Japan) with a Shodex Ionpak KS-801 column (Showa Denko KK, Kawasaki, Japan), following Akiyama [34].

Buffering capacity was measured by the amount of lactic acid at pH 4.0, following McDonald and Henderson's procedure [35].

#### 4.5. Silage Analysis

Silage samples were taken from three round-bales per plot 60 days after ensiling. Subsamples (25 g) were mixed with 200 mL of distilled water and stored in a refrigerator at 5 °C overnight. The extracts of silage samples from Experiments 1, 2, and 3 were measured for pH value, NH<sub>3</sub>-N, and organic acid. The pH value was analyzed by a pH meter (S20 SevenEasy pH, Mettler-Toledo AG, Schwerzenbach, Switzerland). Ammoniacal nitrogen (NH<sub>3</sub>-N) concentration was analyzed by a Kjeltac analyzer (Kjeltac system 1035, FOSS A/S Co. Ltd., Hillerød, Denmark). The organic acid concentration was analyzed via a direct UV method in Experiments 1 and 2, and by a BTB post-labeling method in Experiment 3, using the same HPLC system with a Shodex RS Pak (KC-811 column, Showa Denko K.K.), following the Association of Self-Supply Feed Evaluation [36] guidelines. The total nitrogen (TN) concentration in silage was analyzed by the Kjeltac analyzer used in Experiments 1 and 2.

V-score values for assessing the silage fermentation quality in Experiments 1 and 2 were determined from the concentrations of acetic acid, propionic acid, butyric acid, caproic acid, valeric acid, NH<sub>3</sub>-N, and TN [36]. The silage quality in Experiment 3 was evaluated using the same parameters as in Experiments 1 and 2, except for the fermentation quality, which was evaluated using the V2-score [36].

#### 4.6. Statistical Analysis

Independent *t*-tests and an analysis of variance by one-way analysis procedures were carried out using StatView for Windows software ver. 5.0 (SAS Institute Inc., Cary, NC, USA). Differences between means were evaluated at 5% probability using a Tukey–Kramer procedure.

### 5. Conclusions

It was here demonstrated that fermentation quality of dwarf napiergrass silage ensiled in the summer season can be improved by adding LAB and that ensiling high-moisture material in autumn proved to be good without any additives and did not lead to the need of wilting due to an absence of the positive effects of wilting or additives on the fermentation quality in autumn. Thus, dwarf napiergrass defoliated by a flail-type harvester and ensiled by a round-baler without additives in autumn can produce satisfactory fermentation-quality silage, which is surely applicable to small-holder cow-calf breeding farmers in the region. Ensiling chopped forage with high moisture often produces an effluent from silages. Thus, a new research target is to investigate the effect of wilting on silage fermentation quality of dwarf napiergrass by adopting a practical apparatus for ordinary cow-calf farmers, such as mowers and round-balers.

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**Author Contributions:** S. Fukagawa and Y. Ishii conceived and designed the experiments; S. Fukagawa performed the experiments and analyzed the data; I. Hattori contributed materials and analysis tools; S. Fukagawa and Y. Ishii wrote the paper.

**Conflicts of Interest:** The authors declare no conflict of interest.

### Abbreviations

The following abbreviations are used in this manuscript:

napiergrass	<i>Pennisetum purpureum</i> Schumach
LAB	Lactic acid bacteria
AC	<i>Acremonium</i> cellulase
FJLB	Fermented Juice of Epiphytic Lactic Acid Bacteria
TDN	Total Digestible Nutrient
DM	Dry Matter
CP	Crude Protein
IVDMD	In vitro Dry Matter Digestibility
NH <sub>3</sub> -N	Ammoniacal Nitrogen
TN	Total Nitrogen
LB/ST	Ratio of Leaf Bade to Stem with Leaf Sheath

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