Silage Characteristics of Forage Ramie and Comparison of Nutrient Composition and Feeding Value Before and After Ensiling: Postprint

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Abstract

To investigate the effects of chopping length on the silage characteristics of forage ramie, the experiment chopped forage ramie into three lengths of 1, 2, and 3 cm, ensiled for 60 days, then conducted sensory evaluation and laboratory analysis on the samples, and compared these with the nutritional components and feeding value of forage ramie before ensiling. The results showed that: 1) The fermentation quality of forage ramie silage in the 1 and 2 cm groups was graded as Grade 1 (excellent), while that in the 3 cm group was graded as Grade 2 (fair). 2) There were no significant differences in the ratio of ammonia nitrogen to total nitrogen and the contents of acetic acid and propionic acid among the 1, 2, and 3 cm groups ($P > 0.05$); the pH of forage ramie silage in the 2 cm group was significantly lower than that in the 1 and 3 cm groups ($P < 0.05$); the lactic acid content of forage ramie silage in the 2 cm group was significantly higher than that in the 1 and 3 cm groups ($P < 0.05$). 3) There were no significant differences in the contents of crude protein, crude fat, crude fiber, neutral detergent fiber, and acid detergent fiber before and after ensiling of forage ramie ($P > 0.05$); however, the crude ash content in the 3 cm group was significantly lower than that in the other groups ($P < 0.05$), and the gross energy in the 1 and 3 cm groups was significantly higher than that in the 2 cm group and the pre-ensiling forage ramie group ($P < 0.05$). 4) There were no significant differences in dry matter intake (DMI), digestible dry matter (DDM), and organic matter digestibility (OMD) of roughage before and after ensiling of forage ramie ($P > 0.05$); however, the relative feeding value (RFV) of the 1 cm group was the lowest, significantly lower than that of the 2 cm group ($P < 0.05$). Comprehensive analysis indicated that forage ramie silage with a chopping length of 2 cm demonstrated superior fermentation characteristics, nutritional composition, and feeding value, showing greater practical value for production applications.

Full Text

Feeding Ramie: Silage Characteristics and Comparison of Nutrient Composition and Feeding Value before and after Silage

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Abstract: To explore the effect of chop length on the silage characteristics of feeding ramie, feeding ramie was chopped into three lengths (1, 2, and 3 cm) and ensiled for 60 days. Samples were then subjected to sensory evaluation and laboratory analysis, with nutrient composition and feeding value compared before and after ensiling. The results showed: 1) The fermentation quality of 1 and 2 cm feeding ramie silage was graded as excellent (Grade 1), while the 3 cm group was graded as good (Grade 2). 2) No significant differences were observed in ammonia nitrogen to total nitrogen ratio and acetic and propionic acid contents among the three groups ($P>0.05$). The pH of the 2 cm group was significantly lower than that of the 1 and 3 cm groups ($P<0.05$), while its lactic acid content was significantly higher ($P<0.05$). 3) No significant differences were found in crude protein, ether extract, crude fiber, neutral detergent fiber, and acid detergent fiber contents before and after ensiling ($P>0.05$). However, the crude ash content of the 3 cm group was significantly lower than other groups ($P<0.05$), and the gross energy of the 1 and 3 cm groups was significantly higher than the 2 cm group and pre-ensiled ramie ($P<0.05$). 4) No significant differences were observed in dry matter intake (DMI), digestible dry matter (DDM), and organic matter digestibility (OMD) before and after ensiling ($P>0.05$). However, the relative feed value (RFV) of the 1 cm group was the lowest, significantly lower than the 2 cm group ($P<0.05$). Comprehensive analysis indicates that 2 cm chop length provides optimal fermentation effect, nutrient composition, and feeding value for feeding ramie silage, demonstrating high practical production value.

Key words: feeding ramie; silage; nutrient composition; feeding value

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Introduction

As the conflict between human grain consumption and livestock feed becomes increasingly prominent, herbivorous livestock, as a grain-saving animal type, have gradually become the main source of meat, dairy, and other animal products for residents [1]. Therefore, producing high-quality forage is an important material foundation related to the development of animal husbandry and even national livelihood. Southern China belongs to tropical and subtropical climate zones with good natural resource advantages suitable for planting high-yield forage, but the high rainfall and temperature also impose higher requirements for forage preservation conditions [2]. Silage is the most economical and practical method for forage preservation, which reduces pH through anaerobic fermentation of lactic acid bacteria to produce organic acids, thereby inhibiting undesirable microbial fermentation and achieving the goal of reducing nutrient loss and preserving green forage long-term [3]. Currently, the main raw material for silage is corn, providing roughage for ruminants year-round, especially during winter and spring seasons [4-5]. However, China has numerous other forage resources that can be developed and utilized. Ramie is widely cultivated in southern China with high crude protein (CP) content, making it a high-quality unconventional roughage. Traditional hay preparation is time-consuming, labor-intensive, and susceptible to weather factors, particularly limited during the hot and rainy season in southern China. Wu Duanqin et al. [6] reported that ramie silage could replace 33%-67% of alfalfa hay in Holstein dairy cow diets without affecting production performance, milk composition, or serum indices, while improving total antioxidant capacity in cow serum. Tuo Nianchu et al. [7] also demonstrated that ramie silage could replace 25% of concentrate feed for Xianan cattle.

Chopping raw materials is an essential step in silage and the foundation for ensuring silage quality. However, no studies have been reported on the effects of chop length on feeding ramie silage. Therefore, this study chopped feeding ramie into three different lengths (1, 2, and 3 cm) to investigate the effects of different chop lengths on its silage characteristics, while simultaneously comparing nutrient composition and feeding value before and after ensiling, aiming to provide reference for further development and utilization of feeding ramie.

1.1 Experimental Materials and Preparation

Feeding ramie (Zhongsi Zhu No. 1) was chopped into three different lengths (1, 2, and 3 cm) using a sickle cutter. Bag silage (25 kg per bag) was adopted, with six bags per treatment. After 60 days of ensiling, three bags were randomly selected for sample collection and analysis. Meanwhile, non-ensiled feeding ramie was collected for nutrient composition determination.

1.2 Sensory Evaluation

Sensory evaluation was conducted according to the silage quality sensory scoring standards of the German Agricultural Association (DLG) (Table 1) [8].

Table 1 Silage quality sensory scoring standard

Sensory indices	Scoring standard	Score	Grade
Smell	Strong butyric acid or ammonia odor, or almost no sour smell	0-5	4 (Poor)
	Heavy butyric acid odor, or pungent burnt or moldy smell	6-10	3 (Fair)
	Weak butyric acid odor, or strong sour smell with weak aroma	11-15	2 (Good)
	No butyric acid odor, strong aroma or obvious bread fragrance	16-20	1 (Excellent)
Structure	Severe stem and leaf rot or contamination	0-5	
	Extremely poor stem and leaf structure, or slight mold/contamination	6-10	
	Poor stem and leaf structure	11-15	
	Good stem and leaf structure	16-20	
Color	Severe discoloration, dark green or yellow	0-5	
	Slight discoloration, pale yellow or brownish	6-10	
	Close to original color, light brown after drying	11-15	
Total Score		16-20	Grade 1 (Excellent)
		10-15	Grade 2 (Good)

1.3 Sample Analysis

For pH determination: 20 g of silage sample was taken, mixed with 180 mL distilled water, stirred thoroughly, left to stand for 2 h, then filtered through gauze and filter paper, and measured with a pH meter. Crude protein, ether extract

(EE), crude ash (Ash), crude fiber (CF), neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents were determined according to the method of Zhang Liying [9]. Gross energy (GE) was measured using an automatic oxygen bomb calorimeter (Hunan Kaiyuan Instruments Co., Ltd.). Fresh silage sample (10 g) was weighed, mixed with 100 mL distilled water, stirred and oscillated thoroughly with a glass rod, extracted at 4°C for 48 h, and the extract was stored at -20°C for determination of ammonia nitrogen and organic acid contents, and calculation of ammonia nitrogen to total nitrogen ratio. Lactic acid content was determined using high-performance liquid chromatography (Agilent 1290); acetic, propionic, and butyric acid contents were determined using gas chromatography (Agilent 7890A); ammonia nitrogen content was determined using a spectrophotometer (Shimadzu UV-2600).

1.4 Calculation of Feeding Value Indices

Roughage dry matter intake (DMI), expressed as percentage of body weight (%BW), was calculated as follows:

$$DMI(\%BW) = 120/NDF$$

Digestible dry matter (DDM) content, expressed as percentage of dry matter (%DM), was calculated as follows:

$$DDM(\%DM) = 88.9 - 0.779 \times ADF$$

Relative feed value (RFV) was calculated using the relative feed value proposed by the Forage Analysis Committee of the American Forage and Grassland Council [10]:

$$RFV = DMI \times DDM/1.29$$

(based on sheep as animal model).

Organic matter digestibility (OMD, %) was calculated according to the empirical formula:

$$Y = 123.5068 - 2.279X$$

(based on sheep as animal model) [11]; where Y represents OMD and X represents crude fiber content.

1.5 Statistical Analysis

Data were processed using Excel 2013 software. One-way ANOVA was performed using SPSS 21.0 software, and Duncan' s multiple comparison was used for inter-group difference significance testing, with $P<0.05$ considered significant. Results are expressed as mean ± standard deviation.

2 Results

2.1 Sensory Scoring of Feeding Ramie Silage

The sensory scores of feeding ramie silage with different chop lengths are presented in Table 2 . As shown in the table, the 1 and 2 cm groups exhibited color close to the original material, with clear stem and leaf structures, no butyric acid odor, and only slight butyric acid smell, receiving scores of 17 and 16, respectively, and graded as excellent (Grade 1). The 3 cm group showed color close to the original material, slight butyric acid odor, and slightly damaged stem and leaf structure, with a score of 15, graded as good (Grade 2).

Table 2 Sensory scoring of feeding ramie silage

Items	Chop length (cm)		
	1 cm	2 cm	3 cm
Smell	7	7	6
Structure	5	5	5
Color	5	4	4
Score	**17**	**16**	**15**
Grade	**Grade 1 (Excellent)**	**Grade 1 (Excellent)**	**Grade 2 (Good)**

2.2 Analysis of pH, Ammonia Nitrogen to Total Nitrogen Ratio, and Organic Acid Content of Feeding Ramie Silage

As shown in Table 3 , no significant differences were observed in ammonia nitrogen to total nitrogen ratio and acetic and propionic acid contents among the three feeding ramie silage groups ($P>0.05$), with no butyric acid detected in any group. The pH of the 2 cm group was significantly lower than that of the 1 and 3 cm groups ($P<0.05$), though no significant difference existed between the 1 and 3 cm groups ($P>0.05$). Additionally, the lactic acid content of the 2 cm group was the highest, significantly higher than both the 1 and 3 cm groups ($P<0.05$), with the 1 cm group significantly higher than the 3 cm group ($P<0.05$).

Table 3 Analysis of pH, NH3-N/TN and organic acid content of feeding ramie silage

Items	Chop length (cm)		
	1 cm	2 cm	3 cm
pH	5.22±0.25^a	4.34±0.18^b	4.99±0.13^a
NH3-N/TN (%)	1.46±0.32	1.47±0.27	1.67±0.17
Lactic acid (%DM)	3.93±0.09^b	5.51±0.37^a	2.33±0.49^c
Acetic acid (%DM)	3.03±0.24	3.10±0.17	3.03±0.50
Propionic acid (%DM)	1.83±0.24	1.45±0.19	1.86±0.12
Butyric acid (%DM)	ND (not detected)	ND	ND

In the same row, values with different small letter superscripts mean significant difference (P<0.05), while with the same or no letter superscripts mean no significant difference (P>0.05). The same as below.

2.3 Analysis of Routine Nutrient Composition of Feeding Ramie before and after Silage

As shown in Table 4 , no significant differences were observed in crude protein, ether extract, crude fiber, NDF, and ADF contents between the feeding ramie group and the three chop length silage groups (P>0.05). The crude ash content of the 3 cm group was significantly lower than other groups (P<0.05). No significant difference in gross energy was found between the 1 and 3 cm groups (P>0.05), but both were significantly higher than the feeding ramie group and the 2 cm group (P<0.05).

Table 4 Analysis of routine nutrient composition of feeding ramie before and after silage (DM basis)

Items	Feeding ramie group (before silage)	Chop length (cm)		
		1 cm	2 cm	3 cm
CP (%)	15.45±0.57	15.39±1.48	17.12±1.04	16.05±1.04
EE (%)	2.84±0.06	3.53±0.59	2.93±0.74	2.87±0.49
Ash (%)	14.45±0.23^a	14.09±0.38^a	14.05±0.50^a	12.85±0.05^b
CF (%)	28.41±0.34	29.84±0.94	26.91±1.21	27.19±0.98
NDF (%)	52.92±2.64	54.18±0.57	48.23±0.67	50.07±2.42
ADF (%)	38.28±1.03	42.66±0.95	38.71±0.52	39.37±0.90
GE (MJ/kg)	15.31±0.01^b	15.91±0.28^a	15.40±0.06^b	16.06±0.06^a

2.4 Feeding Value Evaluation of Feeding Ramie before and after Silage

As shown in Table 5 , no significant differences were observed in DMI, DDM, and OMD between the feeding ramie group and the three chop length silage groups (P>0.05). The RFV of the 1 cm feeding ramie silage group was the lowest, significantly lower than the 2 cm group (P<0.05), but showed no significant difference from the feeding ramie group and the 3 cm group (P>0.05).

Table 5 Feeding value evaluation of feeding ramie before and after silage

Items	Feeding ramie group (before silage)	Chop length (cm)		
		1 cm	2 cm	3 cm
DMI (%BW)	2.28±0.11	2.22±0.02	2.49±0.03	2.37±0.11
DDM (%DM)	59.08±0.80	55.67±0.74	58.75±2.43	57.93±0.70
RFV	104.23±3.81^ab	95.62±2.11^b	113.41±5.57^a	106.65±5.23^ab
OMD (%)	58.75±0.77	55.50±2.13	62.18±2.76	59.86±2.24

The data were calculated values based on estimating formulas.

3 Discussion

Currently, research on feeding ramie silage is limited, and no targeted evaluation standards exist. The results of this study indicate that chop length affects the sensory scores of feeding ramie silage, with 1 and 2 cm chop lengths achieving excellent fermentation quality (Grade 1), while the 3 cm chop length only achieved good quality (Grade 2). Similarly, Zhang Xiaoyu et al. [12] studied the effects of different chop lengths on carrot seedling silage and found that the sensory evaluation results of the 2 cm group were slightly better than the 4 cm group. Ye Fang et al. [13] investigated the effects of different chop lengths on whole-plant corn silage and observed that the 1.5 and 2.0 cm groups had better sensory evaluation results than the 3.0 cm group. Numerous consistent studies demonstrate that shorter chop lengths yield better sensory evaluation than longer chop lengths, possibly because longer chop lengths make the forage less compactable, leaving more residual air in silage bags and facilitating mold proliferation, which results in poorer sensory quality [14-15].

pH, ammonia nitrogen, and organic acid (lactic, acetic, propionic, and butyric acids) contents can reflect silage fermentation quality. Lower pH, less ammonia nitrogen, and more organic acids indicate better preservation and quality [16-20]. McEniry et al. [17] analyzed the fermentation quality of silage with different chop lengths and found that chopping treatment could reduce pH and ammonia nitrogen content while increasing lactic acid content and improving fermentation quality. Yu Ruhua et al. [18] reported that silage quality decreased significantly with increasing chop length. In this study, no substantial differences were observed in ammonia nitrogen to total nitrogen ratio and acetic and

propionic acid contents among the three chop lengths, with no butyric acid detected. However, the 2 cm chop length feeding ramie silage had lower pH and higher lactic acid content than the 1 and 3 cm lengths, indicating better silage quality. This may be due to increased plant cell wall disruption with shorter chop lengths, enabling faster release of soluble carbohydrates, accelerating microbial utilization, promoting rapid fermentation, and producing more lactic acid with faster pH decline [21-23]. However, the poorer fermentation quality of the 1 cm chop length feeding ramie silage in this experiment may be attributed to the high moisture content of Zhongsi Zhu No. 1, resulting in excessive juice loss after fine chopping. Hou Jianjian et al. [20] observed similar results when studying fermentation quality of high-moisture smooth bromegrass and yellow sweet clover. The effects of different chop lengths on feeding ramie silage quality in this study may be due to their impact on compaction degree, thereby affecting silage quality.

Ren Jizhou [16] proposed that crude fiber content is an important evaluation index for premium forage, with 27% considered premium, 27%-34% medium, and 34% low-grade forage. In this study, the crude fiber content of 2 cm chop length feeding ramie silage was below 27%, classifying it as premium forage, while the 1 and 3 cm chop lengths were medium-grade forage. Crude protein is also an important nutritional indicator, and feeding ramie silage has high crude protein content and nutritional value. The relatively large fluctuation in crude protein content among different chop lengths in this study may be caused by uneven leaf-stem mixing or sampling during ensiling, as crude protein content differs significantly between leaves and stems of feeding ramie [17]. However, chop length had little effect on most routine nutrient composition of feeding ramie silage, with similar conclusions drawn by many researchers studying other forages. Hou Jianjian et al. [20] analyzed Leymus chinensis, smooth bromegrass, yellow sweet clover, and milk vetch silage, finding that chop length had no significant effect on dry matter and crude protein content. Ye Fang [23] studied the effects of different chop lengths on corn silage nutrients and found no significant effect on routine nutrient composition.

RFV is a comprehensive reflection of ADF and NDF in feed and an important indicator for evaluating roughage [24]. RFV >100 indicates good overall nutritional value, with higher RFV representing higher nutritional value. Yang Hong et al. [25] evaluated the nutritional value of sorghum-sudangrass silage from different container positions using RFV as the indicator, finding the highest RFV (108.3) in the lower portion of silage. However, some studies suggest that RFV only provides a rough judgment of overall nutritional value without considering quality, i.e., fiber digestibility [26], indicating certain limitations. OMD reflects crude fiber in feed, with higher OMD indicating better digestibility and utilization characteristics. Yu Ruhua et al. [27] studied silage from different corn varieties and found that Kedo No. 4 and Liaoyuan No. 1 had significantly higher OMD than other varieties. In this study, except for the 1 cm chop length feeding ramie silage, RFV values of the other two chop lengths were >100, indicating high nutritional value, with the 2 cm chop length showing optimal digestibility

and utilization characteristics.

4 Conclusion

Feeding ramie is rich in nutrients with high feeding value, and its nutritional characteristics can be well maintained after ensiling. Different chop lengths have varying degrees of influence on silage quality and estimated feeding value of feeding ramie. Under the conditions of this experiment, the optimal chop length for feeding ramie silage is 2 cm.

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Note: Figure translations are in progress. See original paper for figures.