OPEN ACCESS Asian Journal of Animal Sciences

ISSN 1819-1878
DOI: 10.3923/ajas.2020.16.24

Research Article
Fresh Rice Straw Silage Affected by Ensiling Additives and Durations and its Utilisation in Beef Cattle Diets

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Abstract

Background and Objectives: Rice straw is the most abundant crop by-product in Vietnam, but research on fresh rice straw (FRS) silage is very limited. The objectives of this study were to investigate the effects of ensiling additives and durations on organoleptic characteristics and chemical compositions of FRS silage and to determine the suitable substitution of green grass with FRS silage in growing beef cattle under an intensive production condition. **Materials and Methods:** In Experiment 1, urea, ammonia and lactic acid microbes were employed to mechanically treat FRS bales. The bales were stored indoor up to 16 weeks in separate bags for organoleptic and chemical assessments at different preservation durations. In experiment 2, the best FRS silage from experiment 1 was used to replace VA06 grass in dietary forage with different dry matter levels: No FRS silage (Control), 1/3 FRS silage and 2/3 FRS silage. Fifteen Laid Sind growing cattle were randomly allocated to and individually fed 1 of 3 forage treatments for 12 weeks, after a 2 week adaptation. **Results:** The 2% urea treated FRS (fresh matter basis) (URS) displayed the best quality with stably high pH, yellow color and strong ammoniac odor, highest crude protein content throughout 16 week preservation. The replacement of 2/3 URS reduced daily feed intake, but did not cause significant differences in growth performance. **Conclusion:** These findings suggest that 2% urea is an effective treatment to preserve FRS and URS can replace up to 2/3 green grass in growing beef cattle diets under an intensive production condition.

Key words: Urea treatment, fresh rice straw silage, organoleptic characteristics, feed intake, growth performance, beef cattle

Citation: Don Viet Nguyen and Lam Hoang Dang, 2020. Fresh rice straw silage affected by ensiling additives and durations and its utilisation in beef cattle diets. Asian J. Anim. Sci., 14: 6-24.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice (*Oryza sativa*) is the most popular crop in Vietnam. In 2018, Vietnam produced 44.0 million tonnes of rice[1] and the equivalent amount of dry rice straw was generated. A large majority of rice straw has been burned in the field[2]. Meanwhile, ruminant production with approximately 11.2 million heads mainly depends on cut grasses and agricultural by-products since lack of grazing land[3]. During winter in the North or dry season in the South of Vietnam, cut grasses and pastures only meet about 35-57% total forage demand leading to the death of thousands of buffaloes and cattle. Farmers usually feed dry rice straw as a forage source to their cattle during the time when fresh grass is insufficient because of the fact that feeding only dry rice straw does not provide enough nutrients to the ruminants to maintain high production. Animals fed dry rice straw diet only will even lose their weight[4,5]. However, the percentage of rice straw using in ruminant production remains limited compared to its annual yield[6]. Therefore, increasing the nutritive values of rice straw is very beneficial in the sustainable development of ruminant production.

Rice straw is low and unbalanced nutritive contents, high lignin and silica contents and low content of crude protein which contribute to the low voluntary intake and low rate of digestion[4,7]. For many years, various extensive researches have attempted to improve the nutritional quality of rice straw through physical, chemical and microbial treatments[8-10]. However, most studies in Vietnam have used dry rice straw and adjusted the moisture content. Research on alkaline and microbial treatments of fresh rice straw (FRS) silage is very limited. Therefore, the objectives of this study were to investigate the effects of ensiling additives and durations on organoleptic characteristics and chemical compositions of FRS silage and to determine the suitable substitution of green grass with FRS silage in growing beef cattle under an intensive production condition.

MATERIALS AND METHODS

Two experiments were conducted to synthetically assess the feed characteristics of treated fresh rice straw silage. Experiment 1 was carried out from September-December, 2018 at Hung Vuong University, Phu Tho, Vietnam. In this experiment, FRS was treated with 1 of 3 different additives (urea, liquid ammonia and lactic acid microbes). Experiment 2 was a feeding trial conducted from June-October, 2019 at a commercial farm, Nam Dinh, Vietnam. In the trial, the most effective treatment from experiment 1 was chose to produce FRS silage and then partly replace fresh grass in growing cattle diets. The effects of FRS silage substitution on daily feed intake and growth rate were evaluated.

Experiment 1: Effects of additives and preservation durations on FRS silage.

Silage preparation: Rice (cv.Du Huong) was cultivated in paddy fields in Phu Tho, Vietnam. The rice was harvested and threshed at the maturity stage using a combined harvester (DC-70, Kubota, Osaka, Japan). After harvesting, fresh rice straw was spread in 60 cm wide rows on the fields. A round baler (Star 870, Guoan, Shandong, China) pulled by a tractor (L4508, Kubota, Osaka, Japan) attached a spraying device was used to spray silage additive solutions and roll sprayed fresh rice straw into bales (dimension: 50 cm in diameter, 70 cm in height; weight: 27-32 kg). The FRS silage treatments were as follows:

- **Urea treated fresh rice straw silage (URS):** Two liters of solution containing 600 g of urea were added to a bale of fresh rice straw by the spraying device while it was being rolled
- **Ammoniac treated fresh rice straw silage (ARS):** The 600 mL of liquid ammoniac were diluted with clean water in 2 L of solution and then added to a bale of fresh rice straw while it was being rolled using the spraying device
- **Lactic acid microbes treated fresh rice straw silage (LRS):** The 30 mL of the mixture of *Bacillus subtilis, Saccharomyces cerevisae* and *Lactobacillus acidophilus* with 1.0×10^{8} CFU mL^{-1} each species (Soils and Fertilizers Research Institute, Ha Noi, Vietnam) were diluted with 300 g of molasses and 150 g of salt in 2 L of solution, then added in a bale of fresh rice straw by the spraying device while it was being rolled

After spraying and rolling, each treated bale was manually placed a double-layer bag (dimension: 60 cm in diameter, 130 cm in height) and tightly packed separately 2 layer by irreversible-zipped plastic strings. The inner layer of the silage bag was a nylon bag to create the anaerobic condition of the silage and the outer layer was a plastic sackcloth bag to prevent the inner nylon bag from breaking. Fifteen-treated bales were prepared for each silage treatment to sample three bales at 2, 4, 8, 12 and 16 week after ensiling. The bags are then transported to the Laboratory of the Experimental Center, Hung Vuong University (Phu Tho, Vietnam) and stored indoor at room temperature.

Organoleptic characteristics: The color, odor, mold prevalence of the samples were assessed immediately after opening the ensiled bales following the procedure described by Manaye *et al.*[11]. In brief, during the organoleptic evaluation, three assessors assigned the color of silage bales: Yellowish green, pale yellow, light brown, dark or deep brown. The odor of molasses, alcohol, lactic acid, yogurt, vinegar, burnt tobacco and ammoniac were used to assess the offered silage bales. The prevalence of visible mold was taken by having a look to the ensiling bales by walking around in random order with no opportunity to see each other's judgment. The highest frequently scored judgment was taken as the value of the assessment for each organoleptic parameter. The organoleptic assessments were undergone by the same group of panelists throughout the trial to minimize variations.

Chemical composition analysis: The pH of the silage samples was determined using digital pH meter (Go Direct pH Sensor, Vernier S and T, Beaverton, OR, USA). The samples of fresh rice straw silage from different treatments at different ensiling durations were ground through a 1 mm screen. The total nitrogen contents of URS and ARS were determined from freezing samples following the Kjeldahl protocol of AOAC[12]. The samples were dried in a fan-forced oven to a constant weight at 65^{0}C to determine DM content. Total nitrogen content of LRS was determined from dried samples by the Kjeldahl protocol as described by AOAC[12]. Crude protein (CP) content was calculated by multiplying total nitrogen by 6.25. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the methods of Van Soest *et al.*[13]. The samples were combusted in a furnace at 550°C for 5 h to quantify ash content. Organic matter (OM) was computed as OM = 100-ash.

Statistical analysis: The data were subjected to ANOVA general linear model for a factorial design with 2 fixed factors using the Minitab statistical software[14] version 16.2. In the model, ensiling treatment, duration and their interactions were fitted as fixed effects and pH and chemical compositions were dependent variables. The final statistical model used for the analysis was:

$$Y = \mu + T_i + D_j + (T\times D)_{ij} + E_{ijk}$$

Where:

Y = Dependent variable
μ = Overall mean
T_i = Effect of treatment
D_j = Effect of ensiling duration
$(T\times D)_{ij}$ = Interaction effects of ensiling treatment and duration
E_{ijk} = Residual error

When F-test was significant, mean separations were performed using Tukey's tests for pairwise comparison. Significant effects were declared at $p<0.05$.

Experiment 2: Effects of replacing grass with FRS silage on growing cattle performance.

Silage and grass preparation: From the result of experiment 1, the most effective treatment was chosen to produce 7 t of rice straw silage which was used in a 12 week feeding trial.

The rice (cv. Du Huong) was harvested and threshed at the maturity stage using a combined harvester (DC-70, Kubota, Osaka, Japan). After harvesting, fresh rice straw was treated with the most effective additive with the same procedure as described in experiment 1. The treated bags are then transported to the commercial cattle farm and stored in storage at room temperature. After 2 weeks of ensiling, the silage was started to feed experimental animals. Fresh rice straw samples were collected and stored at -20°C for subsequent analysis.

Varisme 06 (VA06) hybrid grass was intensively cultivated at the farm. It was daily harvested at 45 days cutting intervals. Before supply to the animals both fresh rice straw silage and VA06 grass were chopped into 10-15 cm pieces using a commercial electricity chopper (TTP 150, Aatesco, An Giang, Vietnam).

Animals and experimental design: Fifteen Lai Sind cattle, 12 months of age and 122±3 kg of body weight, were randomly selected and assigned to a completely randomized experimental design. The cattle were vaccinated against foot and mouth disease, de-wormed using Ivermectin and identified by numbered ear tags before commencing the experiment. They were randomly allocated to 1 of 3 forage treatments: 100% VA06 grass (control), the mixture of 67% VA06 grass+33% fresh rice straw silage (DM basis) (1/3 URS) and the mixture of 33% VA06 grass+67% fresh rice straw silage (2/3 URS). The diets were formulated to meet the requirements for maintenance and a desired live weight gain of 400-500 g/day. The forage to concentrate ratio (F:C) of the diets was 75:25 (DM basis). Concentrate was offered as a cooked mixture, separately from the forages. The mixture, which the farm usually feeds to their young cattle, consisted of 90% traditional rice distillers' by-product and 10% corn flour (fresh matter basis). Chopped rice straw silage and VA06 grass were mixed following the above treatments to minimize feed selection. The daily offered amount of concentrate was adjusted based on their body weight at 4 week intervals and fed in 1 time at 6:30 am. Forages were offered daily in 2 equal halves at 7:00 am and 5:00 pm. The daily offered amounts of forage accounted for about 110% of the average daily forage intake measured over the previous 3 days. Each animal was placed in a stall (2×4 m) in the same house and individually fed with unlimited access to clean water and a mineral block (Reva, Konya, Turkey) at all times. The feeding trial lasted for 12 weeks after a 2 week adaptation period.

Feed intake and growth measurements: The offered concentrate and forage were recorded daily. On days 1, 28, 56 and 84 of the experimental period, offered concentrate, VA06 grass and FRS silage samples were collected and stored at -20°C for subsequent analyses. Daily refusals were weighed before morning feeding and sampled for DM determination using a rapid microwave oven technique[15].

During the trial, the cattle were weighed on 2 consecutive days every 4 weeks in the morning before feeding using Ruddweigh 200 walk-over weighing electronic scale (Ruddweigh, Guyra, Australia). Average daily gain was calculated as total body weight gain divided by the number of days on the feeding trial. Feed conversion ratio was computed as the quotient of ADG divided by DMI.

Feed chemical composition analysis: The samples of offered concentrate, VA06 grass, fresh rice straw and fresh rice straw silage were ground through a 1 mm screen. The analysis methods of the chemical compositions of the samples were outlined in detail in experiment 1. The total nitrogen content of URS was also determined from freezing samples.

Statistical analysis: All collected data were analyzed using the Minitab statistical software[14] version 16.2. The ANOVA general linear model analyses were used to fit forage treatments as fixed effects and feed intake and growth performance characteristics as dependent variables. The final statistical model used for the analysis was:

$$Y = \mu + T_i + E_{ij}$$

Where:

- Y = dependent variable
- μ = Overall mean
- T_i = Effect of forage treatment
- E_{ij} = Residual error

When F-test was significant, mean separations were performed using Tukey's tests for pairwise comparison. Significant effects were declared at $p<0.05$.

RESULTS

Experiment 1: The effects of additives and preservation durations on FRS silage.

pH and organoleptic characteristics: The pH of fresh rice straw silage was significantly affected by both ensiling treatment and duration ($p<0.01$, Fig. 1). The pH of URS (9.8) was lower than that of ARS (11.8) at the beginning of ensiling process. However, the pH of URS remained approximately 9.0, while the pH of ARS dropped to 6.0 after 16 weeks of preservation. In contrary, the pH of LRS increased from 3.3-5.2 during the 16 week preservation.

The organoleptic characteristics of FRS silage are illustrated in Table 1. The URS displayed the highest quality with yellow color and strong ammoniac odor throughout 16 week preservation, while dark color and burnt tobacco was observed in LRS. Although, ARS was alkaline treatment, it had yogurt smell after ensiling 8 weeks. During the 16 week preservation, no visible mold was observed in URS bales, whereas LRS and ARS bales appeared visible fungi after ensiling 8 and 12 weeks, respectively. The percentage of visible fungi in ARS and LRS bales increased to 10 and 15%, respectively after 16 week preservation.

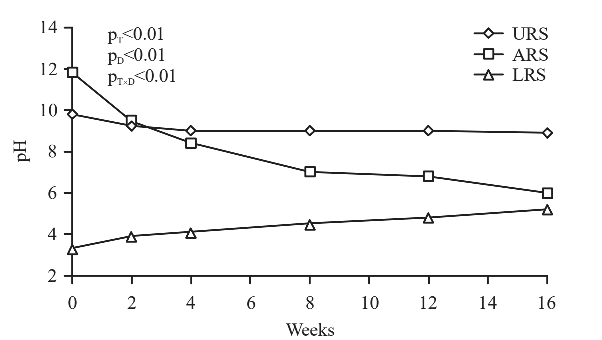

Fig. 1: Changes in pH during 16 week ensilage

URS: Fresh rice straw treated with 2% urea, ARS: Fresh rice straw treated with 2% ammoniac, LRS: Fresh rice straw treated with lactic acid microbes

Table 1: Effects of ensiling treatment and duration on the organoleptic characteristics of ensiled fresh rice straw

		Ensiling duration (week)					
Items	Treatments	0	2	4	8	12	16
Odor	URS	SA	SA	SA	SA	SA	SA
	ARS	SA	SA	SA	Yg	Yg	Yg
	LRS	Mo	Mo	Yg	Vin	Vin	To
Color	URS	YG	YG	Y	Y	Y	Y
	ARS	YG	YG	PY	PY	PY	PY
	LRS	YG	YG	PY	DY	DY	DY
Visible mold (FM (%))	URS	0	0	0	0	0	0
	ARS	0	0	0	0	5	10
	LRS	0	0	0	6	10	15

FM: Fresh matter, URS: Fresh rice straw treated with 2% urea, ARS: Fresh rice straw treated with 2% ammoniac, LRS: Fresh rice straw treated with lactic acid microbes, SA: Strong ammoniac smell, Yg: Like yogurt smell, Mo: Like molasses smell, Vin: Like vinegar smell, To: Like burnt tobacco smell, YG: Yellow green, PY: pale yellow, DY: dark yellow, Y: yellow

Table 2: Effects of ensiling treatment and duration on the chemical compositions of ensiled fresh rice straw

	Treatments			Ensiling duration (week)							p-value		
Items	URS	ARS	LRS	0	2	4	8	12	16	SEM	T	D	T×D
DM (%)	40.6	40.3	39.5	41.1	40.1	39.8	39.3	38.6	42.0	0.05	0.26	0.08	0.11
OM (%DM)	86.3	86.6	85.9	86.4	85.8	86.4	86.3	87.0	85.7	0.02	0.14	0.11	0.35
CP (%DM)	11.3[a]	6.5[b]	3.7[c]	7.6	7.4	7.2	7.1	6.8	6.7	0.06	<0.01	0.99	<0.01
NDF (%DM)	70.6	70.3	69.8	70.4	70.3	69.1	70.7	70.2	70.7	0.03	0.09	0.36	<0.01
ADF (%DM)	38.2	38.7	37.7	37.8	38.8	37.4	38.6	37.8	38.8	0.03	0.10	0.10	<0.01
Ash (%DM)	13.7	13.4	14.1	13.6	14.2	13.6	13.7	13.0	14.3	0.02	0.14	0.11	0.35

DM: Dry matter, OM: Organic matter, CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, URS: Fresh rice straw treated with 2% urea, ARS: Fresh rice straw treated with 2% ammoniac, LRS: Fresh rice straw treated with lactic acid microbes, T: Effects of ensiling treatment, D: Effects of ensiling duration, T×D: Interaction effects of ensiling treatment and ensiling duration, [a,b,c]Means in the same row with different superscripts show significant differences at p<0.05

Table 3: Chemical composition of fresh rice straw and feeds used in the experiment

Items	FRS	URS	VA06 grass	Concentrate mixture
Dry matter (DM) (%)	53.0±3.6	56.3±4.2	15.5±1.5	15.5±0.4
Organic matter (DM) (%)	87.5±0.2	87.6±0.7	91.2±0.5	96.8±0.2
Crude protein (DM) (%)	5.0±0.2[b]	12.7±0.1[a]	8.3±0.3	22.3±0.6
NDF (DM) (%)	71.4±0.5[a]	68.8±0.9[b]	66.0±0.8	27.6±0.6
ADF (DM) (%)	38.1±1,3	38.2±0.8	34.7±1.1	8.4±0.4
Total ash (DM) (%)	12.5±0.2	12.4±0.7	8.9±0.5	3.2±0.2

FRS: Fresh rice straw, URS: Fresh rice straw treated with 2% urea, Means of FRS and URS in the same row with different superscripts differ significantly at p<0.05

Changes in chemical compositions of fresh rice straw silage: Crude protein (CP) was significantly affected by ensiling treatment (p_T< 0.01, Table 2). The CP content was highest in URS (11.3% DM) and lowest in LRS (3.7% DM). However, no differences in other analyzed chemical compositions were observed among the 3 treatments (p_T>0.05). Ensiling duration did not affect the chemical compositions of fresh rice straw silage (p_D>0.05).

Significant interaction effects on CP, NDF and ADF contents were detected ($p_{T\times D}$<0.05, Table 3). The URS at the first 8 weeks recorded the highest CP contents, ranging from 11.4% DM to 12.1% DM), whereas the lowest CP content was observed in LRS at the beginning of preservation (3.0% DM). For NDF contents, the highest (72.8% DM) and lowest (67.5% DM) valued were observed both in ARS at the beginning of preservation and week 4, respectively. The ADF content of URS at week 8 was significantly higher than that of LRS at week 8.

Experiment 2: Effects of replacing grass with FRS silage on growing cattle performance.

Changes in chemical compositions of untreated FRS and URS: The chemical compositions of the untreated fresh rice straw and experimental feed are presented in Table 3. Up to 4 months ensiling, all the URS bags well preserved, with strong ammonia smell, dark brown color and no fungi. With 2% urea treatment, the CP content increased significantly (p<0.05) from 5.0% DM in untreated FRS to 12.7% DM in URS (2.5 folds). In contrast, the NDF content of URS (68.8% DM) was significantly lower (p<0.05) than that of FRS (71.4% DM). Other chemical compositions of fresh rice straw were not affected by urea treatment (p>0.05).

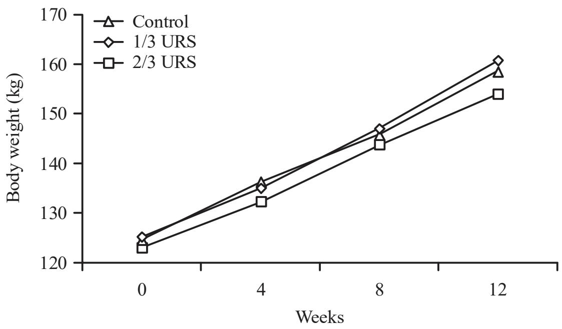

Fig. 2: Changes in body weights during the experimental period
URS: Fresh rice straw treated with 2% urea

Table 4: Feed intake of experimental cattle (kg/day)

Items	Control	1/3 URS	2/3 URS
Fresh matter basis			
Concentrate intake	5.48±0.17	5.60±0.14	5.55±0.15
VA06 grass intake	17.50±0.32	11.47±0.20	5.23±0.10
URS intake	0	1.56±0.03	2.93±0.05
Forage intake	17.50±0.32	13.03±0.22	8.16±0.15
Dry matter basis			
Concentrate DMI	0.85±0.04	0.87±0.03	0.86±0.03
Forage DMI	2.71±0.05[a]	2.65±0.05[a]	2.46±0.05[b]
Total DMI	3.56±0.06[a]	3.52±0.06[ab]	3.32±0.06[b]
OMI	3.31±0.06[a]	3.23±0.05[a]	2.07±0.04[b]
CPI	0.42±0.01[b]	0.45±0.01[a]	0.46±0.01[a]
F:C	3.16±0.04[a]	3.10±0.05[a]	2.87±0.05[b]

URS: Fresh rice straw treated with 2% urea, DMI: Dry matter intake, OMI: Organic matter intake, CPI: Crude protein intake, F:C: Forage to concentrate ratio, means in dry matter basis bearing different superscripts within the same row differ significantly at p<0.05

Table 5: Growth performance of experimental cattle (kg/day)

Items	Control	1/3 URS	2/3 URS
Initial body weight	124.80±6.8	125.20±5.6	123.00±4.5
Final body weight	158.40±5.7	160.60±4.8	153.80±5.9
TWG	33.60±3.9	35.40±2.7	30.80±1.9
ADG	0.40±0.05	0.42±0.03	0.37±0.02
DMI of 100 kg body weight	2.66±0.03[a]	2.62±0.02[ab]	2.52±0.03[b]
FCR	0.11±0.01	0.12±0.01	0.11±0.01
FCE	9.33±0.82	8.58±0.75	9.21±0.63

URS: Fresh rice straw treated with 2% urea, TWG: Total weight gain, ADG: Average daily gain, DMI: Dry matter intake, FCR: Feed conversion ratio, FCE: Feed conversion efficiency, means in the same row bearing different superscripts differ significantly at p<0.05

Feed intakes of experimental animals: The daily feed dry matter intakes were influenced by replacing VA06 grass with URS (p<0.05, Table 4) with the exception of concentrate DMI. The cattle fed forage containing 67% URS had significantly lower forage DMI (2.46 kg/day) than the cattle fed forage containing only VA06 grass and 33% URS (2.71 and 2.65 kg/day, respectively). As a consequence, the forage to concentrate ratio in the control and 1/3 URS treatments were significantly higher than that in the 2/3 URS treatment.

The total DMI in the control treatment (3.56 kg/day) was considerably higher (p<0.05) than that in the 2/3 URS treatment (3.32 kg/day). However, there was no difference in total DMI between the 1/3 URS treatment and the other treatments. The animals in the control treatment had significantly higher organic matter intake (OMI), but lower crude protein intake (CPI) than their counterparts in the 2/3 URS treatment.

Growth performance: Replacing VA06 grass with URS in the cattle diets did not significantly affect their growth performances (p>0.05, Table 5, Fig. 2). No differences in final weight, total weight gain, feed conversion ratio and feed conversion efficiency were observed. Likewise, the ADG are relatively similar among treatments, ranged from 0.37-0.42 kg/day/head. In contrast, there was a significant difference (p<0.05) in the DMI of 100 kg body weight between the control (2.66 kg) and 2/3 URS (2.52 kg) treatments.

DISCUSSION

The primary aim of ensiling forage is to attain acidic (pH<4.5) or alkaline (pH>8) anaerobic condition in silage because the spoiled microbes and fungi in silage are restricted at these pH range[16,17]. As a result, ensiled materials could prolong storage time, decrease nutrient loss and mold appearance[4]. In the present study, the sensory characteristic of URS seemed to be better than the others, due to the stable pH at 9 during 16 weeks of ensilage. The dark yellow color, tobacco burnt smell and the appearance of fungi of the ARS and LRS implied the spoiled silage and poor fermentation. These might be contributed by the weakly acidic pH, which ranged from 4.5-7 after 8 week preservation.

Moreover, the addition of lactic acid microbes conventionally aims to enhance lactic acid production in rice straw silage, resulting in a decrease in pH (below 4.5) and thus increasing silage quality[18,19]. Zhang *et al.*[18] concluded that after 45 day sensiling FRS with higher levels of LAB inoculants containing *Lactobacillus buchneri* and *Pediococcus pentosaceus* (provided by Chr. Hansen Biosystems, Milwaukee, WI, USA), all the silage were well preserved with pH<4.5 and the quality of rice straw silage. In fact, LRS in the present study seems to be in a good condition after 45 days of preservation. Differences in LAB inoculants, addition levels and ensiling time might be the main reason for the difference between the findings of this study and Zhang *et al.*[18] research. Moreover, Ohmomo *et al.*[20] and Li *et al.*[21] stated that the characteristics of LAB inoculants widely vary even within the same species. It is important to note that not all commercial LAB inoculants are always suitable for silage-making in all countries and regions.

In the present study, ensiling treatment considerably influenced the CP content of rice straw silage. Supplementing non protein nitrogen (NPN) such as urea and ammoniac is conventional methods to enhance CP content[4,7]. However, the reduction in pH of ARS during ensiling contributed to the emergence and development of spoiled microbes, which might use NPN for their protein biosynthesis and other metabolic processes[22]. Numerous studies agreed that the inoculation of lactic acid microbes did not improve the CP content of rice straw silage[11,18,19].

In the present study, urea treatment decreased the NDF content of the silage, but the ADF content was not affected, which is consistent with numerous studies[16,19,23]. The decrease in NDF content is due to the reduction in hemicelluloses which was utilized by microorganism for their proliferations during natural fermentation[24]. The effects of urea treatment vary depending on the levels of added urea, the quality of rice straw, the moisture content, loading density and storage method of the silage[19,25,26].

It is obvious that fresh VA06 grass is more palatable than URS because rice straw intrinsically has the high levels of indigestible fiber and anti-nutritional factors such as silica and lignin, limiting voluntary intake[27,28]. Therefore, the replacement of 2/3 fresh grass with URS in this study could reduce forage palatability, resulting in decreases in the voluntary intakes of forage, total feed and organic matter in terms of dry matter. Moreover, the lower OMI in 2/3 URS treatment could partly be attributed to the high total ash content of URS (Table 3). Man and Wiktorsson[26] also stated that the higher levels of urea treated fresh rice straw (>50% DM basic) in the mixed forage treatment resulted in a reduction in palatability and higher indigestible contents in dairy cow diets compared to elephant grass. This would cause low dry matter intakes and forage to concentrate ratio.

The higher CPI in the mixed forage treatments in the present study could be explained by the higher CP content in URS in comparison with that in VA06 grass (Table 3). The outcomes were in accordance with previous studies by Wanapat *et al.*[23] and Gunun *et al.*[29], who fed dairy lactating cows untreated and urea treated rice straw as forage sources. In contrast with these results, Man and Wiktorsson[26] and Sanh *et al.*[25] observed no difference in the CPI of dairy lactating cows when replacing up to 75% fresh grass (DM basic) with urea treated rice straw. The significant differences in their studies were absent because the calculation was based on the CP content after sun-drying urea treated rice straw silage. They also noticed that exposure of urea treated rice straw silage in the atmosphere increased the loss of ammonia and then reduced CPI.

The final body weight, total weight gain and ADG were no significant differences among the treatments clearly indicating that replacing up to 67% fresh grass with URS did not significantly influenced the growth performance of the growing beef cattle. The absence of significant difference in growth performance, although there was a reduction in DMI, in this study could be explained by the higher CPI in the mixed forage treatments (Table 4). The replacement increased the CP content of feed dry matter intake from 11.8% (in control treatment) to 12.7 and 13.8% (in 1/3 and 2/3 URS treatments respectively). This indicates that URS provided additional nitrogen, resulting in higher NH_3-N concentration in the rumen[30]. Obara *et al.*[31] reported that nitrogen supplementation from urea could increase the activity of rumen microorganism in degrading carbohydrates (cellulose, hemicellulose and starch) when the energy level is sufficient. The higher CPI and probably higher ruminal microbial synthesis, fiber digestibility by urea treatment may contribute to the similar growth performance of cattle fed diets containing URS compared to cattle in the control diet.

In the present study, the significant difference in DMI of 100 kg body weight between the control and 67% URS treatments is due to significant difference in total DMI while the body weights of these two treatments were similar. The results were much lower compared to the outcomes of Hossain *et al.*[32], who fed diets containing fresh rice straw treated 3.5% urea and fresh grass to 20 months old female beef cattle. The diversities in breed, age and the level of offered concentrate[26] and dietary nutrient density and expected ADG [33] might explain for these differences.

CONCLUSION

Fresh rice straw can be preserved by common ensilages with different additives. Treating FRS with 2% urea (fresh mater basis) improved the CP content of FRS silage without negative effects on pH, organoleptic characteristics and other chemical compositions during 16 weeks of preservation. The present findings suggested that lactic acid microbes can be added to FRS for up to 2 months of preservation. Substitution of VA06 with URS at up to 67% (DM basis) of the forage in growing beef cattle did not have detrimental effects on growth performance. Urea preservation of FRS for beef cattle can be a sustainable alternative forage source, especially in the winter or dry season in Vietnam.

ACKNOWLEDGMENTS

Financial support from Asian Development Bank (ADB) through Low Carbon Agriculture Support Project (LCASP) is gratefully acknowledged. The authors would also like to thank Dr. Nguyen Van Toan and other members of the Research Institute of Agricultural and Rural Planning for their logistical assistance during the experiments.

SIGNIFICANT STATEMENTS

- Fresh rice straw can be preserved by common ensilages with different additives for cattle as a sustainable alternative forage source
- Treating fresh rice straw with 2% urea (fresh mater basis) improved the crude protein content of silage without negative effects on pH, organoleptic characteristics and other chemical compositions during 4 months of preservation
- Urea treated fresh rice straw silage can be used to replace up to 67% (DM basis) of green grass in growing beef cattle without detrimental effects on growth performance

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