Original Research Article

Enrichment of Ensilage Quality and Nutrients of Whole-Plant Water Hyacinth (*Eichhornia crassipes*) Based Silages

ABSTRACT

Aims:
This study aimed at enriching the ensilaged quality and nutrient contents of whole-plant water hyacinths (WWH) based silages in different recipes.
Study design: Twelve recipes with three replications each were assigned in a completely random design.
Place and Duration of Study: Faculty of Science and Agricultural Technology, Rajamangala University of Technology Lanna, Lampang Campus, Thailand, between October 2018 and September 2019.
Methodology: Treatments were twelve recipes were including: T1= light wilted WWH+ 1.96 % salt, T2 = light wilted WWH + 4.15 % molasses + 8.27 % rice bran, T3 = light wilted WWH + 6.63 % molasses + 15.86% rice bran, T4 = light wilted WWH +8.91% molasses + 22.83 % rice bran, T5 = moderate wilted WWH + 1.59% Salt, T6 = moderate WWH + 11.17 % molasses + 13.33 % rice bran, T7 = moderate wilted WWH + 10.75 % molasses + 25.67 % rice bran, T8 = moderate wilted WWH + 10.36 % molasses + 37.11% rice bran, T9 = extremely wilted WWH + 1.16% salt, T10 = extremely wilted WWH + 5.10% rice bran, T11 = extremely wilted WWH + 4.30 % molasses, T12 = extremely wilted WWH + 4.30% molasses + 5.14 % rice bran. Each recipe was mixed into triplicates of a 30 kg high-density polyethylene plastic bag under anaerobic condition for 30 days.
Results: The results demonstrated that T6, T7, and T8 were quite superior in fermentation characteristics; T3, T4, T6, T7, and T8 were judged outstanding in physical assessment; T4, T6, T7, and T8 were more appropriate in terms of nutritive values.
Conclusion: This work demonstrated that WWH can be upgraded into high-quality silage by wilting, chopping into pieces, adding rice bran and molasses, and ensilaged for about 30 days. The finding from this study indicated that T6, T7, and T8 were fit all aspects and recommended as recipes for producing high-quality WWH-based silage for ruminants.

Keywords: Water hyacinth, ensiling, silage, feed, ruminant.

1. INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) has been classified as a foreign water weed with severe outbreaks in tropical areas. It can multiply and propagate rapidly, resulting in severe adverse effects by obstruction of water flow and water transport. Water hyacinth obstructs the drainage of sluices in the irrigation system, negatively affecting the water flow rate. Dense water hyacinths also block sunlight, which negatively affects the photosynthesis of underwater plants, retarding their growth and ruining ecosystems. However, water hyacinths have some advantages in nutritional values that benefit as feed to animals. Suppose large quantities of water hyacinth could be harvested effectively from water. It could be fed directly to some animals or preserved in the ensilaged form. Tham (2015) reported that whole-plant water hyacinth contained high moisture content, approximately 91.3-94.2 % of the dry matter [1]. Besides, fresh leaves of water hyacinth contained 18.1% crude protein; total leaf petiole had 7.6% crude protein; whereas whole-plant water hyacinth comprised approximately 12.8% of crude protein. Several works have reported that freshwater hyacinths, especially the leaves and petioles or the above-water part, can feed pigs [2, 3] or cattle [4, 5]. Water hyacinths may feed cattle in the dried form [6] or the fermented form [7]. Tham and Uden [7] reported that fermented water hyacinths could be used to fatten cattle in the proportion of 30-45% with rice straw. However, the development of water hyacinth in the form of whole plant silage in combination with local additives or feed ingredients to enrich as a quality roughage is limited. The objective of this research was to develop and evaluate the recipes mainly based on whole-plant water hyacinths combined with available local feed ingredients to become a high-quality silage that benefits ruminant production and might help to relieve those problems of dense water hyacinth infestation, especially in some irrigated or public areas.

2. MATERIAL AND METHODS

Whole-plant water hyacinths (WWH) were collected from irrigation canals and public waterways in Mueang District, Lampang province (latitude 18°21'51.4"N 99°35'49.4"E), Thailand. After collection, whole-plant water hyacinths were allowed to wilt under the sun-dried open-air condition to reduce moisture for light (1-d), moderate (2-d), or extreme (4-d), respectively. Then, it was chopped into small pieces of 5-10 cm length by a multipurpose shredder model MP-003 with a 6.5 horsepower using Hinota® gasoline engine as a supply motor power. Twelve recipes of WWH based silages were developed on a dry matter basis (Table 1) as the following:

T1= light wilted WWH + 1.96 % salt,
T2 = light wilted WWH + 4.15 % molasses + 8.27 % rice bran,
T3 = light wilted WWH + 6.63 % molasses + 15.86% rice bran,
T4 = light wilted WWH + 8.91% molasses + 22.83 % rice bran,
T5 = moderate wilted WWH + 1.59% Salt,
T6 = moderate WWH + 11.17 % molasses + 13.33 % rice bran,
T7 = moderate wilted WWH + 10.75 % molasses + 25.67 % rice bran,
T8 = moderate wilted WWH + 10.36 % molasses + 37.11% rice bran,
T9 = extremely wilted WWH + 1.16% salt,
T10 = extremely wilted WWH + 5.10% rice bran,
T11 = extremely wilted WWH + 4.30 % molasses,
T12 = extremely wilted WWH + 4.30% molasses + 5.14 % rice bran.

All formulas were thinly sprayed with 5% distilled vinegar to stimulate the acidity during the mixing process.

Each recipe was mixed thoroughly into triplicates of 30 kg each in high-density polyethylene plastic bags; then, the anaerobic condition was applied using a handy vacuum cleaner (Mamaru® model MR-2301, China) for 30 seconds before wrapping by ropes. All bags were piled, covered by an opaque tent, and overlayed by wheel tires for 30 days. After finishing ensiling process, approximately 50 g of each replicate was randomly sampled from each bag, cut into small pieces, and crushed within a high-speed blender. About 200 ml of distilled water was added and kept at 4 °C for approximately 24 h [8] filtered with Whatman No. 4 filter paper. Then pH was measured immediately using a pH meter (pHTestr®30, EUTECH, Singapore). Lactic acid, acetic acid, and citric acid were measured by titration [9].

Table 1. Ingredient recipes of WWH based silages (Dry matter basis)

Items	Amount (kg)				Total (kg)
	WWH	Rice bran	Molasses	NaCl	
T1	98.17	-	-	1.96	100
T2	87.56	8.27	4.15	-	100
T3	77.49	15.86	6.63	-	100
T4	68.25	22.83	8.91	-	100
T5	98.39	-	-	1.61	100
T6	75.48	13.33	11.17	-	100
T7	63.57	25.67	10.75	-	100
T8	52.51	37.11	10.36	-	100
T9	98.83	-	-	1.17	100
T10	94.88	5.10	-	-	100
T11	95.68	-	4.30	-	100
T12	90.54	5.14	4.30	-	100

The physical quality characteristics of fermented silages were graded according to the criteria indicated in the handbook of the Department of Livestock Development [10], including 1) odor: fragrant, like pickled fruit or vinegar (12 points); unscented, slightly pungent (8 points); very pungent and slightly foul (4 points); rotten or moldy (0 points); 2) plant texture: firm, with leaves and stems intact and free of impurities (4 points); firm, leaves and stems slightly rotting, slimy (2 points); firm, leaves and stems highly disintegrated, impurity (1 point); mucus and very dirty (0 points); 3) color: greenish-yellow or khaki (3 points); yellowish-green darken (2 points); golden brown (1 point); dark brown or black (0 points); 4) pH 3.5-4.2 (6 points), 4.4-4.7 (4 points), 4.7-5.1 (2 points), > 5.1 (0 points); 5) quality rating: 20-25 (Very Good), 15-19 (Good Quality), 6-14 (Medium Quality), and 0-5 (Low Quality). Only Very Good quality samples were analyzed for dry matter, crude protein, ether extract, ash [9], neutral detergent fiber (NDF), and acid detergent fiber (ADF) [11]. Gross energy (GE) was analyzed using AC500 Isoperibol Calorimeter (Leco, USA). Data were analyzed for variance using Analysis of Variance (ANOVA), mean values were compared by Duncan's new multiple range tests using SPSS 26.0 for Windows, and significance was declared when *P*-value was less than .05 [12]. The statistical model was as the following: $Yij = \mu + \tau i + \varepsilon ij$, where Yij = observation, μ = Overall mean, τi = treatment effect, and εij = random error [13]. For physical assessment, data were analyzed and compared by means using Kruskal-Wallis of a nonparametric method [12]. This experiment was conducted at the Faculty of Agricultural Science and Technology, Rajamangala University of Technology Lanna, Lampang, Thailand, between October 2018 and August 2019.

3. RESULTS AND DISCUSSION

3.1 Effect of wilting on moisture and dry matter contents of WWH

Before the trial, moisture and dry matter contents of WWH were observed in air-dry conditions outdoor to determine moisture changes. In 2018, the average weather conditions were ranged from 21.41 to 33.11 °C, 16.47 to 24.25 °C of dew point, 75.40 % relative humidity, and 5.13 km/h of wind speed (Table 2). Data indicated that the average moisture content of WWH at harvesting from water sources was 63.53% or 36.47% dry matter. Major moisture contents were mainly contained in the root parts. In general, tropical plants should be wilted to reduce their moisture concentration to obtain at least 30% dry matter not only to decline water buffering ability that resists changing of pH, but also enhance the concentration of water-soluble carbohydrate, and prevent loss from silage seepage [14, 15].

In this trial, dry matter contents of WWH at the light (1-d), moderate (2-d), or extremely wilted (4-d) were 50.58, 62.26, and 86.06 %, respectively (Figure 1).

Table 2. Average weather of Lampang, Thailand in 2018[1]

Items	Maximum	Average	Minimum
Maximum temperature (°C)	36.47	33.11	27.54
Average temperature (°C)	30.85	28.09	28.09
Minimum temperature (°C)	24.21	21.41	18.70
Dew point (°C)	24.25	20.73	16.47
Relative humidity (%)	na	75.40[2]	na
Wind speed (km/h)	21.58	5.13	0
Rainfall (mm)	na	1,170[2]	Na

[1]www.wunderground.com; [2]Thai Meteorological Department; [na] Not available

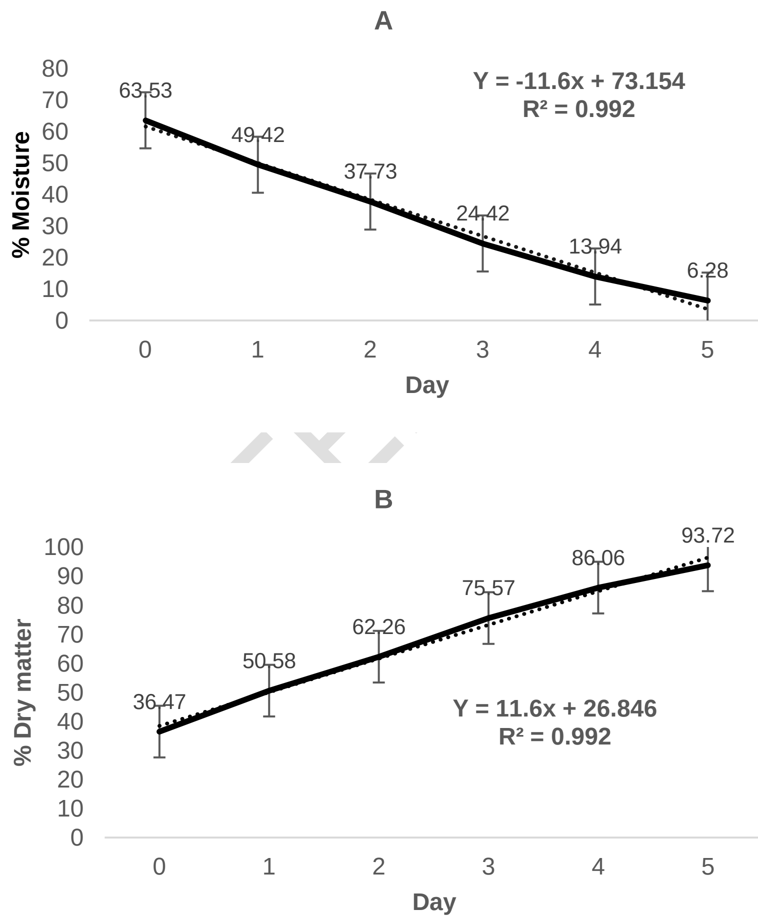

Figure 1. Moisture (A) and dry matter (B) contents of WWH wilted in air-dry condition

3.2 Ensilage quality and nutritive values of WWH-based silages

Values of pH and acidity of whole-plant water hyacinth-based silages in different recipes are shown in Table 3. Because WWH had an unpalatable taste, salt was added 1.17 to 1.96 %DM in T1, T5, and T9 intently to improve the palatability of fermented plants. However, data demonstrated that adding salt did not promote lactic acid bacteria growth. In contrast, it resulted in high pH of about 7.85-8.47 and did not improve nutritional and physical ensilage quality. In general, the most efficient ensiling mechanism, pH should be lower than 4.2, which means upcoming acidity would be able to inhibit the growth of other microorganisms, enabling the preservation of the quality of fermented whole-plant water hyacinths. The pH below 4.2 was found in recipes of T3, T4, T6, T7, and T8 (P = .001). That low pH relies on the mechanism of natural lactic acid bacteria to convert soluble carbohydrates into lactic acids that results in a dropping pH below 4.2 and be able to prevent other microorganisms such as yeast and mold that cause spoilage of fermented plants [16]. In corn silage with pH below 4.2, the typical concentration of lactic acid ranges from 2 to 4 %DM with dry matter content ranging from 25 to 60 %. In this study, lactic acid contents were found relatively higher for T4 (0.71%), T6 (0.73%), T7 (0.89%), and T8 (1.21%) compared to other recipes (P = .001), but all were less than 2%. Surprisingly, the pH was able to maintain below 4.2 due to the combined effects of acetic acid and citric acid that were dominant in this trial. In the case of corn silages, higher pH than 4.2 may be associated with extremely dry before ensiling, overly plant mature, drought-stricken, or low sugar contents [17,18]. High concentrations of acetic acids were found in T2 (2.88%), T3 (3.31%), and T4 (4.77%) (P = .001). In general, acetic acid concentration in silages usually ranges from 1 to 3 %, but approximately 3 to 4 % is often reported in silages treated with *L. buchneri* because of its potential to converse lactic acid to acetic acid [17]. In the high efficiency of silage fermentation, the ratio of lactic acid to acetic acid ratio is usually about 2.5 to 3.0. Acetic acid has an important role in preventing the growth of fungi due to its antifungal characteristics [17]. Citric acid concentrations were found higher in T4 (0.51%), T6 (0.52%), T7 (0.57%), and T8 (0.86%) (P = .001). The benefits of citric acid help improve fermentation quality, limit proteolysis, and improve the fatty acid composition of silage [19]. In terms of fermentation characteristics, those of T6, T7, and T8 seemed to fit the criteria as quality silages for ruminants.

Table 3. Fermentation characteristics of WWH based silages

Items		**%**		
	pH	**Lactic acid**	**Acetic acid**	**Citric acid**
T1	7.85^{e}	0.07^{a}	0.45^{bc}	0.05^{a}
T2	4.59^{c}	0.43^{c}	2.88^{e}	0.22^{bc}
T3	4.19^{b}	0.44^{c}	3.31^{f}	0.35^{d}
T4	3.80^{a}	0.71^{d}	4.77^{g}	0.51^{e}
T5	8.47^{f}	0.21^{b}	0.14^{a}	0.15^{ab}
T6	4.01^{b}	0.73^{d}	0.48^{b}	0.52^{e}
T7	3.85^{a}	0.89^{e}	0.53^{c}	0.57^{e}
T8	3.90^{ab}	1.21^{f}	0.81^{d}	0.86^{f}
T9	7.90^{e}	0.07^{a}	0.05^{a}	0.05^{a}
T10	5.38^{d}	0.20^{b}	0.13^{ab}	0.14^{ab}
T11	4.86^{c}	0.37^{c}	0.29^{abc}	0.31^{cd}
T12	4.64^{c}	0.46^{c}	0.31^{abc}	0.33^{cd}
S.E.	0.17	0.04	0.19	0.07
P-values	0.001	0.001	0.001	0.001

^{abcdefg} different letters in the same column showed a statistically significant difference (P = .05);
T1= light wilted WWH+ 1.96 % salt, T2 = light wilted WWH + 4.15 % molasses + 8.27 % rice bran, T3 = light wilted WWH + 6.63 % molasses + 15.86% rice bran, T4 = light wilted WWH +8.91% molasses + 22.83 % rice bran, T5 = moderate wilted WWH + 1.59% Salt, T6 = moderate WWH + 11.17 % molasses + 13.33 % rice bran, T7 = moderate wilted WWH + 10.75 % molasses + 25.67 % rice bran, T8 = moderate wilted WWH + 10.36 % molasses + 37.11% rice bran, T9 = extremely wilted WWH + 1.16% salt, T10 = extremely wilted WWH + 5.10% rice bran, T11 = extremely wilted WWH + 4.30 % molasses, T12 = extremely wilted WWH + 4.30% molasses + 5.14 % rice bran (dry matter basis).

An assessment of the physical characteristics of WWH-based silages in different formulas is present in Table 4. After fermentation, silage odor would be a good indicator to indicate how well WWH fermented. In well-fermented silage, it may smell the soft odor of lactic acid, the most prevalent volatile fatty acid because lactic acid is nearly odorless [17,20]. Mild vinegar is another possible odor because acetic acid is the second most common volatile fermentation end-product usually ranging from 1 to 3 % of DM [17]. In this study, the odor scores were the highest for T3, T4, T6, T7, T8, and T12 (*P* = .001). These groups characterized odor that smelled like pickled fruit or vinegar. However, T3 and T4 were quite strong in vinegar odor which indicated that silages contained more amount of acetic acid than lactic acid indicating low numbers of lactic acid-producing bacteria due to low sugar or too much moisture contents [20]. Most WWH based silages had a similar texture score except T9. Most outstanding groups were characterized by firm texture, with leaves and stem intact and free of impurities. In the case of poor-quality silage, the texture may be slimy results from the fermentation of clostridial bacteria [20]. The color scores were the highest in T3, T4, T6, T7, T8 (*P* = .001) with greenish-yellow or khaki color. The pH scores, an excellent indicator to measure the acidity of silage, were the highest for T4, T6, T7, and T8. Moreover, the total scores were also the highest for T4, T6, T7, and T8 (*P* = .001). These findings were consistent with the fermentation aspects of various forage crops reported by several works [16, 21, 22].

In terms of physical assessment, those of T3, T4, T6, T7, and T8 were evaluated to have superior physical characteristics.

Table 4. Physical assessment of WWH-based silages

Items	**Odor**	**Texture**	**Color**	**pH**	**Total score**	**Quality**
T1	4.00^{a}	4	2.33^{ab}	0.00^{a}	7.33^{a}	Medium
T2	8.00^{c}	4	2.67^{bc}	2.67^{b}	18.67^{e}	Good
T3	12.00^{d}	4	3.00^{c}	4.67^{c}	24.33^{g}	Very Good
T4	12.00^{d}	4	3.00^{c}	6.00^{c}	25.00^{g}	Very Good
T5	8.00^{c}	4	2.00^{a}	0.00^{a}	14.00^{bc}	Medium
T6	12.00^{d}	4	3.00^{c}	6.00^{c}	25.00^{g}	Very Good
T7	12.00^{d}	4	3.00^{c}	6.00^{c}	25.00^{g}	Very Good
T8	12.00^{d}	4	3.00^{c}	6.00^{c}	25.00^{g}	Very Good
T9	6.67^{b}	2	2.00^{a}	0.00^{a}	12.67^{b}	Medium
T10	8.00^{c}	4	2.33^{ab}	0.00^{a}	14.33^{c}	Good
T11	8.00^{c}	4	2.00^{a}	2.67^{b}	16.67^{d}	Good
T12	12.00^{d}	4	2.00^{a}	2.00^{b}	20.33^{f}	Very Good
S.E.	0.66	-	0.28	0.82	0.93	-
P-values	0.001	-	0.001	0.001	0.001	-

^{abcdefg}, different letters in the same column showed a statistically significant difference (*P* = .05).

T1= light wilted WWH+ 1.96 % salt, T2 = light wilted WWH + 4.15 % molasses + 8.27 % rice bran, T3 = light wilted WWH + 6.63 % molasses + 15.86% rice bran, T4 = light wilted WWH +8.91% molasses + 22.83 % rice bran, T5 = moderate wilted WWH + 1.59% Salt, T6 = moderate WWH + 11.17 % molasses + 13.33 % rice bran, T7 = moderate wilted WWH + 10.75 % molasses + 25.67 % rice bran, T8 = moderate wilted WWH + 10.36 % molasses + 37.11% rice bran, T9 = extremely wilted WWH + 1.16% salt, T10 = extremely wilted WWH + 5.10% rice bran, T11 = extremely wilted WWH + 4.30 % molasses, T12 = extremely wilted WWH + 4.30% molasses + 5.14 % rice bran (dry matter basis). Smell: fragrant, like pickled fruit or vinegar (12 points); unscented, slightly pungent (8 points); very pungent and slightly foul (4 points); rotten or moldy (0 points). Plant texture: firm, with leaves and stems intact and free of impurities (4 points); firm, leaves and stems slightly rotting or slimy (2 points); firm, leaves and stems highly disintegrated, impurity (1 point); mucus and very dirty (0 points). Color: greenish-yellow or khaki (3 points); yellowish-green or dark green (2 points); golden brown (1 point); dark brown or black (0 points). pH 3.5-4.2 (6 points); 4.4-4.7 (4 points); 4.7-5.1 (2 points); > 5.1 (0 points). Quality Rating: 20-25 (Very Good); 15-19 (Good Quality); 6-14 (Medium Quality); and 0-5 (Low Quality).

Nutrient contents of WWH-based silages are presented in Table 5 and Figure 2. Dry matter of WWH-based silages ranged from 42.19 to 68.73 (*P* = .001). Due to the sticky characteristic of molasses, about 5 to 10 % of water was added to dilute and make the mixing process much easier for recipes that contained molasses. Crude protein was the highest for T4, T6, T7, T8, T10, T11, T12; ranging from 8.26 to 9.16% DM (P = .001). Crude protein found

Table 5. Nutrient composition of WWH-based silages (% dry matter)

Items	DM	CP	EE	NDF	ADF	Ash	GE
T1	42.46^{a}	6.89^{a}	0.96^{a}	53.89	46.10^{ab}	36.24^{cd}	2.12^{a}
T2	42.19^{a}	6.28^{a}	2.91^{bc}	56.55	53.68^{c}	20.98^{ab}	2.81^{abc}
T3	42.37^{a}	6.28^{a}	2.29^{b}	55.93	51.81^{bc}	16.73^{a}	2.50^{a}
T4	42.16^{a}	8.59^{b}	2.50^{bc}	54.12	50.64^{abc}	17.32^{a}	2.61^{ab}
T5	54.48^{b}	6.72^{a}	0.63^{a}	51.74	45.19^{a}	37.98^{d}	2.44^{a}
T6	48.07^{c}	8.26^{b}	2.06^{b}	51.66	49.20^{abc}	22.74^{b}	3.28^{bcd}
T7	55.29^{b}	8.50^{b}	2.54b^{c}	53.37	46.90^{ab}	18.53^{ab}	3.54^{cd}
T8	60.08^{d}	9.16^{b}	3.25^{c}	54.65	46.95^{ab}	17.83^{ab}	3.64^{d}
T9	71.74^{e}	6.99^{a}	0.37^{a}	54.12	48.84^{abc}	44.15^{e}	2.12^{a}
T10	74.12^{e}	8.26^{b}	0.45^{a}	51.66	49.20^{abc}	34.32^{cd}	2.81^{abc}
T11	66.67^{f}	9.16^{b}	0.53^{a}	53.37	46.90^{ab}	33.48^{cd}	2.50^{a}
T12	68.73^{ef}	8.35^{b}	0.55^{a}	54.65	46.95^{ab}	31.98^{c}	2.61^{ab}
S.E.	2.25	0.56	0.49	3.27	2.97	2.76	0.40
P-values	0.001	0.001	0.001	0.725	0.049	0.001	0.001

^{abcdef} different letters in the same column showed a statistically significant difference (P = .05).
WWH = whole-plant water hyacinth, DM = dry matter, CP = crude protein, EE = ether extract, NDF = neutral detergent fiber, ADF = acid detergent fiber, GE = gross energy, kcal/kg. T1= light wilted WWH+ 1.96 % salt, T2 = light wilted WWH + 4.15 % molasses + 8.27 % rice bran, T3 = light wilted WWH + 6.63 % molasses + 15.86% rice bran, T4 = light wilted WWH +8.91% molasses + 22.83 % rice bran, T5 = moderate wilted WWH + 1.59% Salt, T6 = moderate WWH + 11.17 % molasses + 13.33 % rice bran, T7 = moderate wilted WWH + 10.75 % molasses + 25.67 % rice bran, T8 = moderate wilted WWH + 10.36 % molasses + 37.11% rice bran, T9 = extremely wilted WWH + 1.16% salt, T10 = extremely wilted WWH + 5.10% rice bran, T11 = extremely wilted WWH + 4.30 % molasses, T12 = extremely wilted WWH + 4.30% molasses + 5.14 % rice bran (dry matter basis).

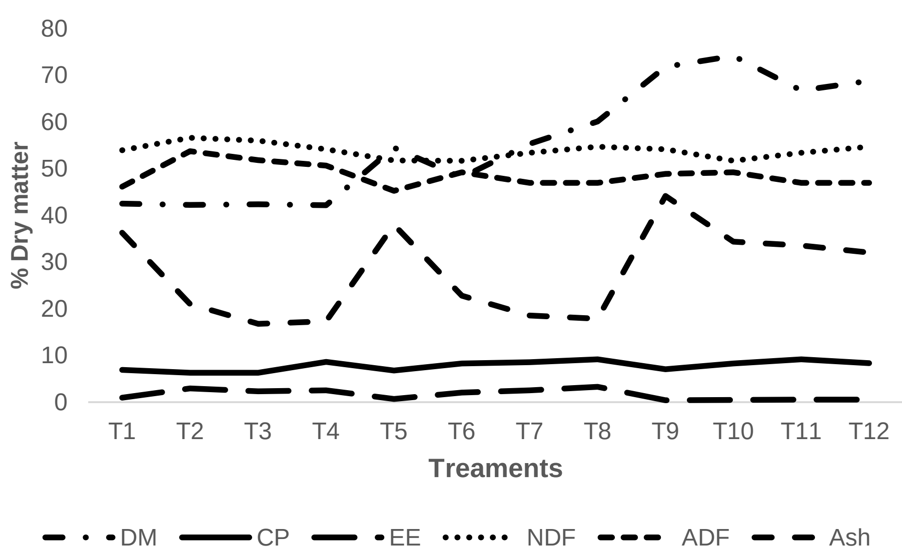

Figure 2. Nutritive values of WWH-based silages

in WWH-based silages was slightly higher than those reported in Napier grass silage that ranging from 6.51 to 7.40% [23, 24]. Those of very good quality of WWH-based silages had crude protein contents closed to corn silages that contained about 8.80-9.90 % CP [25], but lower than those legume silages that contained approximately 10.43-11.30 % CP [26]. In terms of fibers, WWH-based silages had the same amount of NDF (*P* = .725), but a significant difference of ADF (*P* = .049). NDF is an important factor limiting feed intake whereas ADF is an important factor limiting feed digestibility [27]. As dietary fibers increase, ruminant animals will typically spend more time eating, have longer meal length and have greater sorting feed behavior [28]. WWH-based silages were higher in total mineral content (ash) compared to conventional forage because the root parts that can absorb various minerals from the water component were included in the ensiling process. The ramifications of feeding high ash diets to ruminant animals are not well understood, but excessive ash contents in forages or dairy cow diets could be a silent antagonist in the performance of dairy nutrition programs [29]. However, ash was the lowest for T2, T3, T4, T7, and T8 (*P* = .001). In terms of nutritive values and restriction, those of T4, T6, T7, and T8 seemed to fit more criteria than others as quality feeds for ruminants.

4. CONCLUSION

This work demonstrated that WWH can be upgraded into high-quality silage by wilting, chopping into pieces, adding rice bran and molasses, and ensilaged for about 30 days. The finding from this study indicated that T6, T7, and T8 were yield appropriate pH, acid contents, desirable physical appearances, and nutritive values that fit all aspects and were recommended as recipes for producing high-quality WWH-based silage to serve as ruminant feeds.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly used products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge.

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