



Quality and Fermentation Characteristics of Ensiled Water Hyacinth
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Quality Parameters and Fermentation Characteristics of Ensiled Water Hyacinth (*Eichhornia crassipes*)

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ABSTRACT

The present experiment was performed to explore the nutritional potential of wilted Water Hyacinth silage as an unconventional feed resource. A total of seven Water hyacinth silage; six were wilted viz. T1 (Eichhornia 78.9%+ rice straw (RS) 16.84%+ molasses 4.2%) T2 (Eichhornia 78.9%+ RS 16.3%+ molasses 4.2%+Urea 0.52%); T3 (Eichhornia 78.9%+ RS 10.5%+ molasses 4.2%+ wheat bran (WB) 6.3%); T4 (Eichhornia 78.9%+ RS 10.5%+ molasses 4.2%+ moringa 6.3%); T5 (Eichhornia 68.42%+ RS 26.31%+ molasses 4.2%); T6 (Eichhornia 68.42% + RS 26.31%+ molasses 4.2% and Urea 1.05%) and one without wilting T7 (Eichhornia 100%) were prepared. The DM and NDF content was ($P < 0.001$) found to be higher in T-5 and T-6. However, T-3 and T-5 treatment WH silage produced with higher ($P < 0.001$) C.P. content. The fibre content NDF, ADF and cellulose levels were lower ($P < 0.001$) in T-3 and T-4 and higher ($P < 0.001$) RS 26.31% (T5 and T6). Addition of 10.5% RS + 6.3% WB or 6.3% moringa (T3 and T4) resulted in ($P < 0.001$) increase of CP, DM intake (%BW), digestible DM (%), TDN (%), RFV and RFQ. NGP (ml/g) decreased ($P < 0.05$) in T-3 and T-4, whereas OMD (%) and ME (Kcal/g), NDFD%, PF and MBP levels were augmented ($P < 0.001$). WH silage (T7) was especially poor in quality with unacceptable odor and colour. It may be stated that wilted water hyacinth silage may be enhanced with rice straw (10.5%) or wheat bran (6.3%) or *moringa oleifera* (6.3%) and molasses (4.2%) with the view to use as unconventional feed resource in animal feed.

KEYWORDS: Fermentation Characteristics, Quality parameters, Silage, Water hyacinth

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INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is a plant that floats and is found in waters around the globe. The water hyacinth (WH) is recognized for its capacity to purify water waste. Due to its rapid growth, it is considered a noxious water weed that can hinder fish farming and power generation (De Groot et al., 2003). Limited research has been carried out to its use as a feedstuff for the livestock. WH can be fed to fish and pigs (Yang Huazhu et al., 2001) and to ruminants in fresh, dried or ensiled material. Islam et al. (2009) supplemented wilted WH in growing bulls and reported increased protein conversion efficiency and average daily gain (ADG) performance due to increased level of digestible crude protein (DCP) and total digestible nutrients (TDN) content in the diet. However, feed intake is often limited in animals when whole water hyacinth was fed to the animal

instead of feeding after processing (Aregheore and Cawa 2000). Reduction in dry matter intake might be due presence of oxalate crystals which can reduce palatability (Franceschi et al., 1980; Bolenz et al., 1990). Processing through different methods viz. physical and chemical treatments, cooking and fermentation can enhance its nutritive value and utilization of water hyacinths in animal feed (Bolenz et al., 1990; Jafari, 2010)

Ensiling is an effective practice of feed preservation that can improve palatability and enhance nutrient utilization in animals. However, ensiling a high-moisture level materials like water hyacinth remains challenging. Earlier, Water hyacinth dried through shredding or screw-pressing following wilting in a shed for 48 hours (Göhl, 1982). However, later studies reported that the procedure of drying can leads to higher degree of nutrient losses while it can be prevented by different methods of

reconstitution and ensiling water hyacinth with low-moisture feedstuffs, leftover feed ingredients and additives such as urea, molasses and others (Simsa et al., 1993; Indulekha et al., 2019). This study's goal was to examine the nutritional potential of ensiled water hyacinth made with different combinations of rice straw, wheat bran, moringaoleifera, urea and molasses.

MATERIALS AND METHODS

Trial area and procurement of material

The study was carried out during the year 2024 at the Department of Animal Nutrition, Guru AngadDev Veterinary and Animal Sciences University (GADVASU), Ludhiana, India (30°56'22" N, 75°52'22" E, 247 m above sea level) between November 2021 and February 2022. The study was planned to examine the nutritional potential of wilted Water hyacinth silage as an unconventional feed resource. The Water hyacinth was collected from the College of Fisheries Science, GADVASU,

Ludhiana, Punjab, India and wilted for 48 hours in the shade.

Preparation of silage

The wilted water hyacinth was chopped (into 2-4 cm) pieces, separately mixed with different feed ingredients and ensiled for 45 days in low-density polypropylene tubes bags. Total weight of each WH silage treatment bag was 95 kg. A total of seven Water hyacinth silage (Table 1); six were wilted viz. T1 (Eichhornia 78.9%+ rice straw (RS) 16.84%+ molasses 4.2%) T2 (Eichhornia 78.9%+ RS 16.3%+ molasses 4.2%+ Urea 0.52%); T3 (Eichhornia 78.9%+ RS 10.5%+ molasses 4.2%+ wheat bran (WB) 6.3%); T4 (Eichhornia 78.9%+ RS 10.5%+ molasses 4.2%+ moringa 6.3%); T5 (Eichhornia 68.42%+ RS 26.31%+ molasses 4.2%); T6 (Eichhornia 68.42%+ RS 26.31%+ molasses 4.2% and Urea 1.05%) and one without wilting T7 (Eichhornia 100%) were prepared.

Table 1. Ingredient composition of silage prepared from *Eichhornia* in kgs

Ingredients	Wilted water hyacinth Silage (kg)						
	T-1	T-2	T-3	T-4	T-5	T-6	T-7
Eichhornia	75	75	75	75	65	65	95
Molasses	4	4	4	4	4	4	-
Rice straw	16	15.5	10	10	26	25	-
WB	0	0	6	0	0	0	-
Moringa	0	0	0	6	0	0	-
Urea	0	0.5	0	0	0	1	-
Total (kg)	95	95	95	95	95	95	95

Estimation of nutrient content

Chemical analysis of water hyacinth prior to ensiling and after each treatment method was done by drying samples in hot air oven (Narang Scientific Works, India) at 60 °C in a period of 48 hrs to determine dry matter (DM). All samples were homogenized in a laboratory using Wiley mill to pass a 1-mm sieve and then analysed in respect to crude protein (CP), ether extract (EE), total ash, organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF) (Van Soest et al., 1991) and acid detergent lignin (ADL) under proximate

(AOAC, 2005). The method used to determine cellulose was that of Crompton and Maynard (1938).

Estimation of TDN, net energy lactation, relative feed values and relative feed qualities of silage

Parameters such as total digestible nutrient (TDN), net energy for lactation (NE_L), dry matter intake as a percentage of body weight (DMI% BW), Digestible dry matter, (DDM%), relative feed value (RFV) and relative feed quality (RFQ) were calculated by using equations given by Schroeder (2004) to evaluate the nutritive potential of the

different treatment silages.

$$\text{DMI (\% BW)} = 120 / (\% \text{ NDF})$$

$$\text{Digestible dry matter (DDM)} = 88.9 - (0.779 \times \% \text{ ADF})$$

$$\text{RFV} = (\% \text{ DDM} \times \% \text{ DMI}) / 1.29$$

$$\text{RFQ} = (\text{TDN} \times \text{intake}) / (16.8 + 39.2)$$

$$\text{TDN} = 87.84 - (0.79 \times \% \text{ ADF})$$

$$\text{NEI (Mcal/kg)} = 0.0245 \times \text{TDN} - 0.12$$

Estimation of *in vitro* gas productions and digestibility

The procedure of rumen liquor involved taking rumen fluid in the morning without feeding male buffaloes fitted with rumen fistulas and subjected to diet with 2 kg conventional concentrate mixture, 17 kg green fodder and 3 kg wheat straw. The rumen was sampled in the thermo bottle and immediately moved to the laboratory and thereafter passed through 4 layered muslin cloth. The SRL was preserved in 39% and the addition of CO₂ circulation was fixed. This was followed by SRL dilution (1:4 v/v) in the culture media (which contained the macro, micro-mineral solution, medium resazurin, as well as a bicarbonate buffer solution as yourself, according to Menke and Steingass, 1988) and the *in-vitro* assay approach to gas production was adopted which included the measurement of feed digestibility, net gas production (NGP) as well as OM and measuring the NDF digestibility (Van Soest and Robertson, 1988). The amount of gas was figured to derive ME (Menke et al., 1979). A partitioning factor (PF) was determined in accordance with the description of the procedure provided by France et al. (1993).

Statistical analysis

The one-way analysis of variance (ANOVA with full factorial design and fixed factor of treatment) was used to write data concerning chemical constitutions of every variety. All the statistical processes were carried out in SPSS (2012) and posthoc was conducted using Tukey b test and significance was set at P<0.05

RESULTS AND DISCUSSION

Dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), and acid detergent fiber (ADF) contents of silage prepared with various treatments were statistically similar (Table 2). The chemical composition of wilted water hyacinth fell within the range reported in previous studies (Li et

al. 2007; Tham et al., 2013). The DM content of Water hyacinth silage in various treatment groups ranged from 17.2 to 25.5% DM, and the silage without it was found to be 7.25% DM. DM content was reported highest in T-5 and T-6, while lowest in T-7. CP and EE content were found (P<0.001) higher in T-4 and T-6 silage. These findings have an agreement with previous studies (Liu et al., 2001; Tham et al., 2013; Indulekha et al., 2019) reported the addition of wheat bran with molasses can enhance DM, CP, WSC and their fermentation characteristics. However, ensiling Water hyacinths remain challenging due to their high moisture content. Baldwin et al. (1974) found unsuccessful in achieving good fermentation quality with water hyacinth. Wilting of water hyacinth done in sheds can regulate water activity and their moisture level desired for the ensiling. However, prolonged wilting can lead to an excess loss of dry matter, nutrients and water-soluble carbohydrates (WSC) which can also reduce acetic acid levels in ensiled fodder and affect silage quality (Liu et al., 2001). Therefore, the findings of present the study can suggest most suitable combination of Water hyacinth silage with feed ingredients and additives that can expedite wilting, prevent nutrient loss and improve its quality. Usually, rice straw used as a complement of dry matter and to provide absorbent properties, while wheat bran serves as a source of WSC for silage (Malek et al., 2008; Liu et al., 2001).

Results (Table 2) indicate that fibre content NDF, ADF and cellulose in T-4 and T-3 reduced (P<0.001) and found to be higher (P<0.001) in T-5 and T-6 treatment WH silage. However, NDF, ADF and cellulose content was also found lower in T-7 silage and similar to T-3 and T-4, however, DM content in T-7 WH silage was lowest in all silages therefore, results are not completely relatable to the T-3 and T-4 silage treatments. Therefore, the finding suggested that adding dry matter through wheat bran or moringa instead of rice straw can increase CP and WSC content while adding DM through rice straw can increase fibre content (NDF and ADF) in wilted water hyacinth silage. Variation in results from different studies might be due to the different additives, feed ingredients and plant material used for silage. Studies have suggested that ADF and NDF content are reduced with the addition of 10% wheat bran (Li et al., 2007), *moringaolifera* or urea and molasses (Abo-Donia et al., 2022). A lower ADF is inversely related to a higher total digestible nutrients (TDN) value, which indicates higher feed intake and feed utilization in animals.

Table 2. Nutrient composition and feed values of silage prepared from wilted *Eichhornia*

Parameter	T-1	T-2	T-3	T-4	T-5	T-6	T-7	SEM	P value
Nutrient composition, % DM									
Dry matter	21.2 ^c	17.2 ^b	21.4 ^b	21.4 ^b	25.0 ^c	25.5 ^c	7.25 ^a	0.638	<0.001
Crude protein	7.92 ^c	8.20 ^c	6.34 ^a	14.9 ^c	7.29 ^b	13.0 ^d	16.3 ^f	0.119	<0.001
Ether extract	2.00 ^b	1.90 ^b	1.90 ^b	2.37 ^c	1.35 ^a	1.35 ^a	1.60 ^b	0.113	0.001
Neutral detergent fiber	66.3 ^d	61.7 ^c	58.1 ^b	53.9 ^a	69.6 ^c	67.9 ^{dc}	60.4 ^{bc}	0.770	<0.001
Acid detergent fiber	52.1 ^{cd}	48.8 ^c	37.8 ^b	37.2 ^b	49.7 ^c	55.5 ^d	30.7 ^a	1.307	<0.001
Acid detergent lignin	6.70 ^{cd}	7.45 ^d	5.23 ^a	6.03 ^{bcd}	5.37 ^{abc}	6.95 ^d	4.10 ^a	0.387	0.004
Cellulose	45.4 ^d	41.6 ^c	32.6 ^b	31.2 ^b	44.4 ^{cd}	48.5 ^e	26.6 ^a	0.998	<0.001
Hemi-cellulose	14.2 ^{ab}	12.7 ^a	20.3 ^d	16.7 ^{bc}	19.9 ^{cd}	12.1 ^a	29.6 ^e	0.917	<0.001
Ash	18.0 ^b	20.1 ^d	16.2 ^a	15.6 ^a	18.8 ^c	19.0 ^e	16.0 ^a	0.170	<0.001
Organic matter	82.0 ^c	79.8 ^a	83.8 ^c	84.4 ^d	81.2 ^b	81.0 ^b	84.0 ^d	0.170	<0.001
Feed values									
Dry matter intake, % BW	1.80 ^{ab}	1.94 ^c	2.06 ^d	2.23 ^e	1.72 ^a	1.77 ^{ab}	2.01 ^d	0.023	<0.001
Digestible dry matter, %	48.3 ^{ab}	50.7 ^b	59.4 ^c	59.9 ^c	50.1 ^b	45.4 ^a	65.0 ^d	1.018	<0.001
Total digestible nutrients, %	50.4 ^{ab}	53.5 ^b	61.4 ^c	61.8 ^c	53.0 ^b	48.7 ^a	66.3 ^d	0.915	<0.001
Relative feed value	67.9 ^a	76.5 ^b	95.1 ^c	103 ^d	67.0 ^a	62.4 ^a	100.0 ^{cd}	2.167	<0.001
Relative feed quality	1.67 ^a	1.86 ^b	2.35 ^{cd}	2.46 ^d	1.63 ^a	1.54 ^a	2.35 ^d	0.048	<0.001
NE _L , M cal/kg	1.14 ^{ab}	1.19 ^b	1.38 ^c	1.39 ^c	1.18 ^b	1.07 ^a	1.50 ^d	0.022	<0.001

NE_L: Net energy lactation; SEM: standard error mean.

Values with different superscripts varied significantly in a row (P<0.05).

Water hyacinths are characterized by bulbous and elongated petiole structures with relatively low dry matter content, which may affect intake (Parsons and Cuthbertson 2001). Results from the study showed (Table 2) that T-3 and T-4 WH silage found higher dry matter intake (% body weight), dry matter digestibility (DMD%), TDN and net energy for lactation (NE_L). Additionally, the relative feed value (RFV) of water hyacinth silage was higher in T-4 treatment, and relative feed quality (RFQ) was higher for treatments T-4 and T-7. RFV and RFQ values are commonly used through in-vitro models. The RFV is a parameter used to predict voluntary feed intake and assess the quality of the feed, using the NDF and ADF content in the feed. Relative feed

value and quality of silage was enhanced with the addition of urea and molasses. The supplementation of wheat bran and moringaolifera in silage decreases ADF and NDF and improves the feed value and feed quality. Similarly, other trials (Hundal et al., 2019; 2020; Gursoy et al., 2023; Abo-Donia et al., 2022) have recorded the impact of additives in the values of RFQ and RFV of different usual fodder silages (maize/wheat) and non-conventional fodder silages.

Results pertaining to in-vitro gas production method (Table 3) suggests that net gas production, total organic matter digestibility (TOMD) and metabolizable energy were higher in treatments, T-3 and T-4. The ME can of the WH silages without

wilting were 5.41 MJ/kg, which denote that the addition of wheat bran or moringa to the WH silages along with urea and molasses raised the ME content of the T-3 and T-4 sets. On the same note, the ME of silage was also found to have a similar effect with molasses and urea addition to it (Li et al., 2014; Gursoy et al., 2023). T-4 and T-3 groups were also found to have higher ($P<0.001$) level of neutral detergent fibre digestibility (NDFD%), partitioning

factor (PF) and microbial biomass production (MBP), but lower ($P<0.05$) level of NGP. Reason of increased NDFD digestibility might be lower NDF and ADF levels in these groups due to addition of wheat bran or moringa in silage. Microbial protein and PF values increases as the gas production decreases, which indicated efficiency of feed shifted towards microbial protein production (Gursoy et al., 2023).

Table 3. Fermentation Characteristics of wilted *Eichhornia* silage

Parameter	T-1	T-2	T-3	T-4	T-5	T-6	T-7	SEM	P value
NGP, ml/g	64.6 ^{bc}	72.5 ^c	55.4 ^{ab}	51.2 ^a	55.0 ^{ab}	55.6 ^{ab}	43.7 ^a	3.327	0.007
NDFD, %	40.3 ^c	40.3 ^c	49.2 ^d	41.6 ^c	27.7 ^a	34.0 ^b	21.4 ^a	0.430	<0.001
TOMD, %	48.6 ^b	53.9 ^c	55.8 ^d	58.2 ^e	47.9 ^b	48.0 ^b	41.9 ^a	0.430	<0.001
PF, mg/ml	7.71 ^a	7.60 ^a	9.77 ^{bc}	11.5 ^c	8.73 ^{ab}	8.63 ^{ab}	9.62 ^{abc}	0.546	0.006
MBP, mg/g	423 ^b	488 ^c	485 ^c	533 ^d	426 ^b	426 ^b	377 ^a	4.694	<0.001
ME, MJ/kg	4.66 ^{ab}	4.76 ^{abc}	5.26 ^d	5.13 ^{cd}	4.83 ^{bc}	4.46 ^{ab}	5.41 ^a	0.110	0.005

Values with different superscripts in a row varied significantly ($P<0.05$).

The study highlights the potential benefits of using different feed ingredients combinations of additives and dry matter sources to improve the nutritional quality and fermentation characteristics of water hyacinth silage. Proper evaluation of unconventional feed sources is essential before incorporating them into ruminant diets.

CONCLUSION

The livestock and agriculture sectors are essential to social and economic development in rural India. Sustainable livestock farming can be possible with enough fodder availability. One way to increase fodder availability is to utilize unconventional feed for the profitability of livestock husbandry. Therefore study was conducted to know the nutritional potential of ensiled water hyacinth silage to be used as an unconventional feed resource for animals. Results indicate that wheat bran or *moringaolifera* with urea and molasses were the most suitable combinations for Water hyacinth silage preparation, and can improve nutritional composition (DM, CP, EE) nutritive value (DM digestibility, TDN, RFV and RFQ) and fermentation characteristics (NDFD, TOMD and MBP). Supplementing moringa or wheat bran along with rice bran, urea and molasses can improve water hyacinth utilization in animal feed and can assure sustainable fodder availability.

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