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Research article

Nutrient content and *in vitro* degradation study of some unconventional feed resources of Bangladesh

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ABSTRACT

This study aimed to evaluate six unconventional feed resources of Bangladesh, including water hyacinth (*Eichhornia crassipes*), banana leaves (*Musa paradisiaca*), roadside grass (*Stenotaphrum secundatum*), bamboo leaves (*Bambusa vulgaris* Scrad), Seaweed (*Hypnea* sp.) and sugarcane bagasse (*Saccharum griffithii*). Evaluations were based on dry matter (DM), crude protein (CP), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), ether extract (EE), ash content, DM and OM digestibilities and fractional rate of degradation. Two conventional feeds, i.e., rice bran and german grass, were used as the positive control. Samples (400 mg) were incubated with rumen liquor in an *in vitro* fermentation chamber at 0, 6, 12, 24, 48, 72, and 96 h for the degradation kinetic studies. The CP contents of 10.13, 10.63, 10.21, and 8.49 % were found in seaweed, banana leaf, water hyacinth, and bamboo leaf, respectively. The NDF values ranged between 16.5 and 75.6% and ADF varied from 9.7 to 58.8% in this study. The highest value of NDF (75.6%) and ADF (58.8%) were found in sugar cane bagasse and the lowest value of NDF (16.5%) and ADF (9.7%) were as observed in seaweed. However, higher DM degradation (33.5–42.8%) was found in seaweed during the incubation periods of 24–96 h. A significant ($P < 0.05$) increased of OM degradation (44.9%) compared to other feed resources was also observed in seaweed at 96 h of *in vitro* incubation. Water hyacinth, banana leaves, german grass, and sugarcane bagasse had greater DM digestibility (32.9–36.3%) compared to roadside grass, bamboo leaves, and rice bran (24.8–29.1%). The higher total OM digestibility of seaweed found (>44.9%) can be associated with the presence of large quantities of fraction b (>39.2 %), resulting in moderate amounts of undegradable fraction (U) (57.2 %). This study provides a comparative estimate of ruminal DM and OM degradation characteristics for seaweed and some other unconventional feed resources, which might be helpful for their inclusion in the diet according to the ruminally undegraded to degraded DM and OM intake ratio.

1. Introduction

In Bangladesh, an open and semi-intensive livestock production system is generally practiced. The country lacks policies on feeding nearly 25.8 million bovines, 17.3 million caprines and ovines, and 135.1 million poultry (BBS, 2018). The shortage of feeds and fodder has long been identified as a severe constraint to the optimum development of livestock production in Bangladesh. The limitation of feeds and fodder was incredibly recognized. It is also equally important how the available unconventional feed resources and wastes are inefficiently utilized. Developing technology using these unconventional feed resources may reduce total feed cost and be practical for smallholder livestock production in diverse village conditions (Islam et al., 2017). The naturally grown green grasses are primarily available in the fallow land, playground, and roadsides which are significant sources of green forages for rural people of Bangladesh (Islam et al., 2002). A survey of rural goat farmers revealed that 96% of farmers use roadside grass and tree (Samad, 2021). The main barrier to animal production is the feed cost, and this

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may be reduced by using aquatic plants such as water hyacinth, which grows in almost all stagnant water bodies in Bangladesh. During the monsoon, it multiplies rapidly and spreads quickly in newly inundated flood lands. The common water hyacinth is vigorous growers known to double their population in two weeks. Water hyacinth is a good source of CP content ranging from 13.9 to 33.0 % of dry matter (DM) (Khan et al., 2002). They are also relatively high in Ca, P, and Na contents and very rich in K, Fe, Mg, Mn, Cu, and Zn concentrations. Banana leaves are a valuable source of roughage in many tropical countries. Particularly, it can be used as an energy feed-in drought or feed shortage (Reynolds, 1995). The production of banana leaves is 706×10^3 tons in Bangladesh, according to the Yearbook of Agricultural Statistics (2016). ***In vitro*** studies revealed that 50% of the total dry matter of the ground banana stalk disappeared after 24 h fermentation (Poyyamozhi and Kadirvel 1986).

Sugarcane bagasse is another essential unconventional feed resource of Bangladesh, and its annual production is 800,000 tons, according to the Yearbook of Agricultural Statistics (2016). Despite its poor nutritional quality due to its low protein and high lignin contents, it is a prospective source of energy. The bamboo leaf is a good substitute for hay, especially in the dry season (Mekuriaw et al., 2012). In Bangladesh, 33 species of bamboo have so far been found; of these, 7 occur in the forests naturally. The rest are cultivated in the home garden throughout the country to fulfill the daily needs of village people (Banik, 1994). Seaweed may be classified as red (Rhodophyta), brown (Phaeophyta), and green seaweeds (Dawczynski et al., 2007). Seaweed species abundantly grow in the coastal water of St. Martin's Island, Cox's Bazar. Livestock prefers seaweeds and has a long history of use as animal feed. Seaweeds are rich in nutrients containing vitamins, protein, minerals, fiber contents, and essential fatty acids (Ortiz et al., 2006).

Hence, unconventional feed resources could partly fill the animal feed supply chain gap, diminution competition for food between humans and animals, decrease per unit feed cost, and support self-sufficiency in nutrients from locally available feed sources. However, adequate physicochemical characterization of the feedstuff is needed to adequately predict its nutritive value using mathematical modeling (Tedeschi and Fox, 2020). The present studies evaluated six unconventional feed resources of Bangladesh compared with two other conventional feed, german grass and rice bran, in terms of nutrient content and ruminal DM and CP degradation characteristics.

2. Material and methods

2.1. Experimental site

The study was conducted at the Department of Animal Science and Nutrition and the Laboratory of Animal Nutrition of the Faculty of Veterinary Medicine and Animal Science of BSMRAU. This locality is located at 24°05′ North latitude and 90°50′East longitude at an elevation of 9 m above sea level.

2.2. *In vitro* degradation study of unconventional feed resources

2.2.1. Collection, preparation and storage of samples

Freshly flushed naturally grown pre-flowering water hyacinth (*Eichhornia crassipes*) was collected from BSMRAU canal, banana leaves (*Musa paradisiaca*) at the stage of fruiting obtained from the horticultural farm of BSMRAU, naturally grown semi-mature roadside grass (*Stenotaphrum secundatum*) obtained from BSMRAU campus, and semi-mature bamboo leaves (*Bambusa vulgaris* Scrad) from the nearby forest of BSMRAU. All the above samples were collected between March and April 2020. German grass (*Echinochloa polystachya*) samples were collected from the fodder production plot of the livestock and poultry farm of BSMRAU. The first harvest/cut, which was performed after 40–45 days on the plantation during the period of April and May 2020, was used for this research. All the german grasses were harvested by cutting two inches top of the base/root. Rice bran was collected from a livestock feed shop near BSMRAU. Rice bran was stored in the shop at 12 °C in a 37 kg packet for the customers. Five kilograms of locally grown sugarcane (*Saccharum griffithii*) were purchased from the local market for harvesting sugarcane bagasse between March and April 2020. All samples were sundried, followed by oven dry at 65 °C for 2 days, and kept in the zipper bag for further analysis.

Seaweed (*Hypnea* sp.) was collected from the coast of Saint Martin Island, Cox's Bazar, Bangladesh. Collected seaweed was washed with clean seawater several times and transported to the laboratory-using icebox. Seaweed was then washed thoroughly with fresh water to remove epiphytes, sand, and other impurities. The cleaned seaweed was then left to dry in sunlight, packed in plastic bags, and stored at -18 °C until analysis. The samples were collected between March and April 2020.

2.2.2. Grinding of samples

Dried samples were ground to pass through a 2-mm screen using a Wiley mill (AOAC 1990). The final weight of the samples was measured, and subsamples were taken and stored in a plastic zipped bags at 4 °C until further chemical analyses and *in vitro* degradation study.

2.2.3. Collection and preparation of the rumen fluid

Rumen liquor was collected from fresh rumen contents taken from pre contacted slaughtered cattle immediately after evisceration and incision of the rumen at Gazipur Sadar, Gazipur, Bangladesh. The material was then sent to the laboratory using a warm vacuum flask within 1 h. The experimental procedures were in agreement with the ethical principles in animal experimentation of the Committee of Ethics in Animal Experimentation of the BSMRAU, Bangladesh. Then the rumen content was squeezed from the fibrous mass into a spotless plastic beaker (250 mL) through four layers of cheesecloth into an Erlenmeyer flask with an O_2-free headspace. In the absence of CO_2, exposure to oxygen was minimized after filling the vacuum flask with boiled water and covered tightly until the time for accumulating rumen contents at the slaughterhouse. The water was quickly swapped with rumen content directly after the rumen was incised. The cap of the vacuum flask was fixed tightly, leaving no headspace and escaping leakage during the entry period of transport to the laboratory.

2.2.4. Preparation of the inoculums and incubation of the samples

The collected ruminal fluid was flushed with CO_2 and maintained at 39 °C. It was then mixed with the pre-warmed phosphate-bicarbonate buffer at 1:4 ratio to prepare the inoculums (McDougall, 1948). Immediately the flasks were screw-capped and kept in a water bath to maintain 39 °C until further use. Feed samples (0.4 g) were held in the nylon bag, weighed, and adequately transferred to 125-ml Wheaton flasks, which contained a small Teflon-covered stir inside. Each flask was filled with 40 ml of inoculums described above under CO_2, closed with butyl rubber stoppers, and crimp sealed with Aluminum caps. All flasks were placed in the shaking incubation chamber. The incubation chamber was closed when the internal temperature was 39 °C. Every Wheaton flask was collected after finishing the incubation period to measure the degradation. Four samples were replicating, and flasks were incubated in the incubation chamber at 0, 6, 24, 48, 72, and 96 h.

2.2.5. Preparation of fermentation residue and IVDMD or IVODM calculation

After the incubation, residues were washed in running tap water until clear the sample containing the nylon bag. Then the DM and OM values were used for the estimation of *in vitro* DM (IVDMD) and (IVOMD) degradability by using the following equation where A is either DM or OM:

$$\text{IVDMD or IVOMD (g/kg)} = [(\text{g Sample A-g Residue A})/\text{g Sample A}] \times 1{,}000$$

2.2.6. Residue analysis

The DM and OM degradation analysis was carried out according to the procedure described by Mehrez and Ørskov (1977). After the withdrawal of the nylon bags from the incubator were thoroughly washed with running cold water until no further colored liquid could be extruded. The dry matter or organic matter loss for each incubation period was recorded. The DM and OM degradation data were fitted to the exponential equation of Ørskov et al. (1983) as follows:

$p = a + b\,(1 - e^{-ct})$, when a, b and c are constants

Here,

p = the actual degradation after time, t;

a = intercept of the degradation curve at time zero. This represents the component of the protein degraded rapidly relative to the degradation of the component described by b $(1 - e^{-ct})$;

b = potential degradability of the component of the protein which will, in time, be degraded;

c = rate constant for the degradation of value 'b'.

The total degradability a + b cannot exceed 100. The undegradable portion follows as 100 - (a + b) represents the fraction that appeared to be in the rumen.

2.2.7. Chemical analysis

Proximate analysis of the samples was done at the Animal Nutrition Laboratory of BSMRAU. Crude ash was determined after incinerating 1 g of the sample at 600 °C for 6 h in a muffle furnace. Dry matter was estimated at 105 °C overnight in an oven. The nitrogen content was determined using the macro Kjeldahl Method and multiply 6.25 for CP determination (AOAC, 1990).

Crude fat was determined by the petroleum ether extraction method as adapted in the BSMRAU laboratory practice using the Soxhlet extractor. Feed samples were also analyzed at BSMRAU for cell wall constituents (NDF and ADF) according to Goering and Van Soest et al. (1991).

2.3. Statistical analysis

The degradation variations of unconventional feed resources were analyzed by one-way ANOVA with repeated measures using the program Statistix 10. To compare the treatment means, Tukey's multiple range test was used. P-value <0.05 was considered statistically significant.

3. Results

3.1. Nutrients content of feed ingredients

Feed nutrients are an important factor in the evaluation of feed samples. Table 1 shows the major nutrients content of unconventional feed resources. DM content ranged between 12.23 and 91.84%. The DM content was higher (91.84%) in banana leaves than in other unconventional feed resources. Bamboo leaves had 61.8 % DM. CP content of all feed resources ranged between 3.81 and 10.63%. However, seaweed, banana leaves, and water hyacinth showed around 10% CP in each, indicating a good protein source for livestock. Except for seaweed and water hyacinth, all remaining feed resources had more than 29.35 % of crude fiber (CF). The highest crude fiber (46.27%) was found in roadside grass, and the lowest (6.90%) CF was observed in seaweed. Water hyacinth, Banana leaves, and Bamboo leaves showed 49.8 and 54.8 % NDF and more than 29.8% ADF (Table 1). Roadside grass, sugar cane bagasse, and german grass had NDF values of 64.3, 75.6, and 65.9%, respectively. Lower NDF and ADF were found in seaweed and rice bran compared to other unconventional feed resources. The ash content was higher (14.19%) in seaweed, followed by water hyacinth (12.46%) and bamboo leaf (11.45%).

3.2. In vitro DM degradability of unconventional feed resources

In vitro DM degradability of unconventional feed resources in periods has been shown in Table 2. There was a significantly different ($p < 0.05$)

Table 1. Major nutrients content of unconventional feed resources of Bangladesh.

Feed Sample	DM (%)	Nutrients content (%) DM basis					
		CP	CF	NDF	ADF	EE	Ash
Road side grass	14.43 ± 0.59	8.34 ± 0.12	46.27 ± 2.45	64.3 ± 2.89	33.9 ± 1.90	0.93 ± 0.02	5.68 ± 0.23
Water hyacinth	12.23 ± 0.34	10.21 ± 0.78	23.72 ± 1.23	54.8 ± 4.80	29.8 ± 1.23	1.89 ± 0.34	12.46 ± 0.98
Banana leaves	91.84 ± 4.5	10.63 ± .35	29.35 ± 2.5	49.8 ± 3.6	36.8 ± 2.8	8.43 ± 0.19	9.78 ± 0.87
Bamboo leaves	61.8 ± 2.3	8.49 ± 0.87	35.56 ± 2.50	54.7 ± 3.9	38.9 ± 1.5	4.67 ± 0.19	11.45 ± .90
Seaweed	18.78 ± 0.93	10.13 ± 0.83	6.90 ± 0.98	16.5 ± 1.9	9.7 ± .12	3.56 ± 0.08	14.19 ± 1.2
Sugar cane bagasse	89.90 ± 4.6	3.81 ± 0.07	37.89 ± 3.6	75.6 ± 3.7	58.8 ± 4.9	0.50 ± .01	4.87 ± .07
German grass	21.27 ± 0.98	7.51 ± 0.92	39.84 ± 2.9	65.9 ± 5.8	40.2 ± 4.5	3.49 ± .09	6.21 ± .05
Rice bran	89.23 ± 5.8	6.88 ± 0.78	41.2 ± 1.8	37.7 ± 3.0	17.9 ± 1.2	8.67 ± .08	9.67 ± .07

DM = dry matter, CP = crude protein, CF = crude fiber, EE = ether extract.

Table 2. *In vitro* DM degradation of various non-conventional feed available in Bangladesh.

Sample name	Degradation (%)					
	Time Interval (hour)					
	0	6	24	48	72	96
Road side grass	6.0 ± 1.0^{a}	17.5 ± 1.9^{a}	19.4 ± 1.2^{ad}	23.7 ± 1.5^{a}	25.9 ± 3.2^{a}	29.1 ± 1.9^{ad}
Water hyacinth	7.8 ± 1.8^{a}	14.4 ± 2.6^{ab}	18.1 ± 1.6^{ad}	24.8 ± 0.6^{a}	31.1 ± 1.6^{b}	34.8 ± 3.6^{a}
Banana leaves	3.9 ± 0.6^{a}	17.2 ± 0.6^{a}	22.7 ± 1.2^{a}	25 ± 1.0^{a}	29.2 ± 1.7^{ab}	36.3 ± 2.3^{a}
Bamboo leaves	5.3 ± 0.5^{a}	12.8 ± 0.4^{b}	13.1 ± 0.6^{c}	15.9 ± 0.7^{bd}	18.0 ± 0.5^{c}	24.8 ± 0.8^{bd}
Seaweed	3.6 ± 0.7^{a}	17.8 ± 1.7^{a}	33.5 ± 1.6^{b}	39.6 ± 1.6^{c}	40.0 ± 1.8^{d}	42.8 ± 1.9^{c}
Sugar cane bagasse	9.5 ± 0.6^{b}	19.6 ± 0.8^{a}	21.0 ± 0.9^{a}	23.9 ± 1.6^{a}	28.1 ± 1.8^{a}	32.9 ± 1.9^{a}
German grass	6 ± 0.7^{a}	16.5 ± 1.9^{ab}	21.6 ± 1.7^{a}	27.1 ± 2.4^{a}	29.3 ± 2.4^{a}	33.1 ± 3.1^{a}
Rice bran	9.8 ± 0.9^{b}	15.5 ± 1.5^{ab}	16.5 ± 1.6^{ad}	18.7 ± 1.4^{d}	19.2 ± 1.8^{c}	25.6 ± 2.6^{d}

a,b,c,d,e in the same column differ significantly ($P < 0.05$).

of washing loss at '0' hour time in rice bran (9.8 %) and sugar cane bagasse (9.5 %) compared with remaining feed resources (3.6–6%). The highest washing loss was found in rice bran and the lowest in seaweed at '0' h. Comparable trends of degradation (14.4–19.6 %) were observed in most unconventional feed resources except bamboo leaves (12.8%) after 6 h of incubation. It is noticeable here that at 6 h incubation, all feed ingredients' degradation was almost half of the total degradation up to 96 h (Table 2). However, significantly ($P < 0.05$) higher degradation (33.5 %) was found in seaweed after 24 h of incubation. At 24 h of incubation, the lowest degradation was found in bamboo leaves (13.1%). The average degradation at 48 h incubation ranged between 15.9 to 39.6%.

The DM degradation of roadside grass, water hyacinth, banana leaves, sugar cane bagasse, and german grass at 48h ranged between 23.7-27.1%). However, significantly ($P < 0.05$) higher DM degradation was found in seaweed (Table 2) compared to all other unconventional feed resources. Table 2 also shows that the degradation increases with increased incubation time after 72 h incubation with significant ($P < 0.05$) variations of degradation among unconventional feed resources were also observed. Lower degradation was found in rice bran and bamboo leaves (18.7 and 15.9 %). Banana leaves, sugar cane bagasse, and german grass showed similar degradation (28.1 and 29.3 %) at 72 h of incubation. However, at 72 h of incubation, seaweed again showed higher degradation. The highest degradation after 96 h of incubation was found in seaweed and the lowest in bamboo leaves. Some feed ingredients such as roadside grass, water hyacinth, banana leaves, sugar cane bagasse and german grass showed moderate degradation (29.1 and 36.3%) in the current study.

3.3. *In vitro OM degradability pattern of individual, unconventional feed resources*

Incubation time variations of *in vitro* OM degradability of different unconventional feed resources are shown in Table 4. The significantly ($p < 0.05$) higher washing loss of OM was found in sugar cane bagasse (8.89%) and rice bran (9.43%) compared to other unconventional feed resources. The remaining feed ingredients had less than 5% (Table 4). Sugarcane bagasse and seaweed had higher (20.21 and 23.3%) degradation after 6 h of incubation than the remaining unconventional feed resources (11.0–15.02%). At 6 h of incubation, the highest degradation was found in seaweed (23.2%) and the lowest in water hyacinth (11.0 %). We observed half of OM degradation of the total incubation period occurred at 6 h of incubation and found increased OM degradation at increased time points in the same pattern of DM degradation. At 24 h of incubation, the OM degradation had a similar pattern with 6 h of incubation. The improvement was not high except for seaweed. The highest OM degradation at 24 was also found in seaweed (34.1%) and the lowest in bamboo leaves (12.1%).

The variations of OM degradation of different feed ingredients at 48 and 72 h of incubation were slow. They did not differ except for seaweed Table 4. We observed OM degradation of seaweed almost double (44.9%) compared to all other feed resources at 96 h. However, at the end of incubation at 96 h, we observed higher OM degradation in seaweed and lower in roadside grass and water hyacinth. The remaining feed resources of banana leaves, bamboo leaves, sugar cane bagasse, german grass, and rice bran showed moderate OM degradation after 96 h of incubation Table 4.

3.4. *Degradation characteristics*

The mean DM degradation variables across the feeds are presented in Table 3. The mean for the filterable and soluble DM fraction ranged from 3.6 and 10.1% of feed resources. The fraction 'b' the potential degradability of the component ranged between 15.5 to 39.2 %. The significantly ($P < 0.05$) higher potential degradability b (39.2%) was found in seaweed compared to all other feed resources, and the lowest was found in rice bran (Table 3). The mean values of the U fraction, or ruminally undegradable DM, were highest for bamboo leaves (75.2 %) and lowest in seaweed (57.2 %). The mean percentages for the degradation rate 'c' of the degradable 'b' fraction for DM showed no significant ($p < 0.05$) difference (Table 3).

The average OM degradation has been presented in Table 5. The mean washing loss and soluble OM fraction ranged between 2.3 to 9.5 % of feed resources. The fraction 'b' the potential degradability of the component ranged between 18.4 to 44.9 %. The significantly ($P < 0.05$) higher potential degradability 'b' (44.9 %) was found in seaweed compared to all other feed resources, and the lowest was found in roadside grass (18.4%) (Table 5). The mean values of the U fraction, or ruminally undegradable OM, were highest for roadside grass (78.5 %) and lowest in seaweed (52.8 %). The mean percentages for the degradation rate c of the degradable b fraction for OM were not differing significantly ($p < 0.05$) (Table 5).

4. Discussion

The practical importance of feed evaluation is evident with respect to optimizing the efficiency of feed utilization, production, and financial return to the producers (Dijkstra et al., 2007). The nutrient content of feed resources is one of the critical factors for satisfying those. The CP content of the water hyacinth, banana leaves, and seaweed was generally higher in this study, which is above the 7% CP requirement for ruminants that should provide ammonia required by rumen microorganisms to support optimum microbial growth (Njidda et al., 2013). The high CP content of seaweed is well documented and is one of the main distinctive characteristics of seaweeds. Mwalugha et al. (2015) reported 21.39% CP in *Hypnea* spp, which is higher than our studies. Sugar cane bagasse had higher (75.6%) NDF compared to all other feed ingredients (Table 1), which was higher than that of 58% reported by Romao et al. (2014).

Table 3. Degradation fractions (a, b, U) of dry matter (DM) of feed resources.

Fractions	Road side grass	Water hyacinth	Bamboo leaves	Sea weed	Sugar cane bagasse	German grass	Rice bran	Banana leaves	Level of Significance
a	6.0^{a}	7.8^{a}	5.3^{b}	3.6^{b}	9.5^{a}	6.69^{a}	10.1^{c}	3.9^{b}	**
a + b	29.1^{a}	34.8^{b}	24.8^{c}	42.8^{d}	33.0^{b}	33.1^{b}	25.6^{c}	40.2^{d}	**
b	23.1^{a}	27.0^{b}	21.2^{a}	39.2^{c}	23.5^{a}	26.41^{b}	15.5^{d}	36.3^{c}	**
U	70.9^{a}	65.2^{b}	75.2^{c}	57.2^{d}	67^{b}	66.9^{b}	74.4^{c}	59.8^{d}	**
c	0.0379	0.0180	0.0204	0.0534	0.0204	0.0348	0.0237	0.0345	NS

a = the intercept of the degradation curve at time zero.
b = the potential degradability of the component of the protein which will, in time, be degraded.
c = the rate constant for the degradation of 'b'.
** = $P < (0.05)$, a,b,c,d in the same row differ significantly ($P < 0.05$).
a + b = the total degradability of the sample by which obviously cannot exceed 100. It follows that 100 - (a + b) represents the fraction which will appear to be undegradable in the rumen.
U = Undegraded portion.

Table 4. *In vitro* OM degradation of various unconventional feed resources available in Bangladesh.

Sample name	Degradation (%)					
	Time Interval (hour)					
	0	6	24	48	72	96
Road side grass	3.45 ± 0.9[a]	11.2 ± 0.9[a]	14.4 ± 1.1[a]	15.7 ± 1.2[a]	17.4 ± 2.2[a]	18.4 ± 1.4[a]
Water hyacinth	4.4 ± 0.8[a]	11.0 ± 1.6[a]	13.9 ± 1.2[a]	15.8 ± 0.9[a]	17.1 ± 1.6[a]	18.6 ± 2.3[a]
Banana leaves	3.59 ± 0.7[a]	12.2 ± 0.5[a]	16.2 ± 1.3[a]	19.95 ± 1.2[c]	24.2 ± 1.4[b]	27.45 ± 1.2[b]
Bamboo leaves	4.3 ± 0.3[a]	11.2 ± 0.5[a]	12.1 ± 0.4[a]	13.4 ± 0.8[a]	16.4 ± 0.7[a]	22.8 ± 0.9[a]
Seaweed	2.27 ± 0.9[a]	23.3 ± 1.6[b]	34.1 ± 1.5[b]	41.2 ± 1.6[d]	44.5 ± 1.8[c]	44.9 ± 1.8[c]
Sugar cane bagasse	8.89 ± 1.1[b]	20.21 ± 0.9[b]	23.34 ± 0.8[c]	26.32 ± 1.4[e]	28.24 ± 1.5[d]	33.1 ± 1.5[d]
German grass	3.86 ± 0.8[a]	12.12 ± 0.9[a]	16.24 ± 1.4[a]	20.01 ± 1.4[c]	21.9 ± 1.4[be]	23.8 ± 2.1[a]
Rice bran	9.43 ± 1.3[b]	15.02 ± 1.2[a]	14.9 ± 1.5[a]	16.27 ± 1.2[a]	16.44 ± 1.4[a]	23.6 ± 1.6[a]

a,b,c,d,e in the same column differ significantly ($P < 0.05$).

The lowest NDF was found in seaweed (16.5%), which agrees with the result of Marsham et al. (2007), who found 14.6% of NDF in *Eisenia bicyclis*. In fact, the chemical composition of seaweed depends on various factors like species, harvesting season, habitat and light, and water temperature, and therefore, significant variability is reported in the literature (Makkar et al., 2016). Andriarimalala et al. (2019) worked on the nutritional potential of bamboo leaves for feeding dairy cattle and observed that the bamboo leaves contained 7.71–15.4 % crude protein. Although bananas are mainly used as human food, their leaves are used as an unconventional diet for livestock. The CP content of Banana leaves was 10.6 which is almost similar to 11.2%(Chali et al., 2018). German grass (Table 1), a conventional fodder for cattle, showed lower CP content compared Kanak et al. (2012). The CP content of sugar cane bagasse and roadside grass was also low (Table 1) but higher in crude fiber that may satisfy animals' dietary fiber. The variations in CP content in feed resources can be explained by inherent characteristics of species related to the ability to extract and accumulate nutrients from the soil or atmospheric nitrogen. The other issues triggering variation in the chemical composition of feed resources include soil type (location), the plant part (leaf, stem, pod), age of leaf, and season (Rittner and Reed, 1992). Usama et al. (2016) found 21.9 % ash in Pelvetia brown seaweed collected in the spring season, higher than our study. Differences in ash content could be due to different habitats where they grow, varying concentrations of inorganic compounds and salts in the water environment, and differing mineralization methods in the species influenced by temperatures and pH (Mendis and Kim, 2011).

Determination of chemical composition is vital for understanding the nutritional properties of feed ingredients, but it is not sufficient (EL Hassan et al. (2000). Therefore, DM and OM disappearance were also studied in the present study. DM disappearance increased with increasing incubation time (Table 2). These results are in agreement with Kirkpatrick and Kennelly (1987), which indicated surges in DM and CP disappearance of barley (*Hordeum vulgare*), canola meal, and soybean meal. The *in vitro* DM apparent disappearance of different feed resources is given in Table 2. Approximately 50% of the total DM loss of feed resources occurred at 6 h incubation. There was an increasing tendency of DM loss of all feed resources at 24 h time; however, interestingly, seaweed had double DM loss at 24 h time. Usama et al. (2016) found *in vitro* digestibility of red seaweeds Mastocarpus after 24 h of incubation at 33.3%, which was almost similar to our findings (Table 2). DM disappearance was highest in seaweed and lowest in the bamboo leaves, suggesting that the DM in seaweed is highly degradable. The higher DM degradation of seaweed might be partially explained by its high soluble fraction b (39.2%). In addition, this can be due to lower fiber in the seaweed (Table 1). The lower DM degradability of all other feed resources can be attributed to its higher fibre content (Table 1), as acid detergent fiber is negatively correlated with DM degradability (Kamalak et al., 2005). The highest degradation was found at 24.80% after 96 h of incubation in Bamboo leaves. Artabandhu et al. (2010) observed 21.2 % *in vitro* apparent digestibility of *Bambusa nutans* in the rumen of cattle at 24 h of incubation, which is double at that incubation period of our study. This may be due to lower soluble fraction of 'b' (21.2%) and different species of bamboo. Herbert and Thomson (1992) studied DM losses up to 48 h to account for the disappearance of fractions of four barley straws using the nylon bag technique and reported that a major part of the DM loss occurred at 48 h. The differences in dry matter loss may be related to variations in chemical composition or differences in physical structure, such as the distribution within the tissues of lignified cells (Ramanzin et al., 1991). Thus, the seaweed and bagasse with a high loss of dry matter may have high levels of cell content and low contents of lignin (not determined), and lignin is the main factor limiting the digestibility in forages Van Soest et al. (1991). The undegradable fractions U were higher in all feed ingredients except seaweed, which is due to the lower degradation of fractions 'b' and 'c', the rate constant for the degradation of 'b' (Table 3). This indicates that seaweed may be a potential feed ingredient compared to conventional rice bran and german grass.

Table 5. Degradation fractions (a, b, U) of organic matter (OM) of feed resources.

Fractions	Road side grass	Water hyacinth	Banana leaves	Bamboo leaves	Sea weed	Sugar cane bagasse	German grass	Rice bran	Level of Significance
a	3.4[a]	4.4[a]	3.59[a]	4.3[a]	2.3[a]	8.9[b]	3.9[a]	9.5[b]	**
a + b	21.5[a]	23.0[a]	31.0[b]	27.1[b]	47.2[c]	42.0[c]	27.7[b]	33.1[b]	**
b	18.4[a]	18.6[a]	27.4[b]	22.8[ab]	44.9[c]	33.1[d]	23.8[a]	23.6[a]	**
U	78.5[a]	77.0[a]	68.9[ac]	72.9[a]	52.8[b]	58.0[b]	72.3[a]	66.9[c]	**
c	0.0214	0.0134	0.0421	0.0321	0.0425	0.0422	0.0245	0.0224	NS

a = the intercept of the degradation curve at time zero.
b = the potential degradability of the component of the OM which will, in time, be degraded.
c = the rate constant for the degradation of 'b'.
** = $P < (0.05)$, a,b,c,d in the same row differ significantly ($P < 0.05$).
a + b = the total degradability of the sample by which obviously cannot exceed 100. It follows that 100 - (a + b) represents the fraction which will appear to be undegradable in the rumen.
U = Undegraded portion.

Feeding diets with at least 12% protein may be necessary to maximize organic matter fermentation in the rumen. Organic matter disappearance from the incubated test sample has been shown in Table 4. Organic matter disappearance of various feed resources was high at 96 h incubation period. The highest 48 h disappearance value of 41.2 % was obtained for seaweed, suggesting that the organic matter in this plant was the most degraded. In this same period, <20% of the organic matter in the remaining feed sources had been lost except sugar cane bagasse 25%. Determining the degradation of organic matter is essential. There is no denying the fact that microbial protein synthesis is highly dependent on the readiness of rumen degradable organic matter (Karshi and Russell, 2001). The feed resources used in this study varied in organic matter degradation characteristics. This may be due to degradable carbohydrates, particularly the non-structural NDF, proteins, and fat, components that may make organic matter readily degradable *in situ* in the rumen (Arieli et al., 1998). German grass and rice bran are very common to feed ingredients in Bangladesh. The pattern of OM degradability of different feed ingredients (Table 4) suggests that unconventional feed resources have better OM degradation than conventional german grass and rice bran. They may contribute as new feed ingredients in animal feeding. The potential degradability of the OM component 'b' of seaweed and sugar cane bagasse which will, in time, be degraded, is higher than our conventional rice bran and german grass, suggesting high potential degradable feed ingredients for animal feeding. This study provided a comparative estimate of some unconventional fed ingredients' ruminal DM and OM degradation characteristics, which might be useful for their inclusion in the diet according to the ruminally undegraded to degraded DM and OM intake ratio.

5. Conclusion

This study shows that CP and total ash contents were higher in seaweed, banana leaf, water hyacinth, and bamboo leaf inspite of a significant variation of *in vitro* DM and OM degradation. Based on our results, this study provided a comparative estimate of ruminal DM and OM degradation characteristics of some unconventional feeds of Bangladesh, which might be helpful for their inclusion in the diet according to the ruminally undegraded to degraded DM and OM intake ratio.

Declarations

Author contribution statement

Abu Sadeque Md Selim and Luis Orlindo Tedeschi: Conceived and designed the experiment; Wrote the manuscript.

Md. Nazimul Hasan and Md. Abdur Rahman: Performed the experiment.

Md. Morshedur Rahman and Md. Rashidul Islam: Analyzed and interpreted the data.

A. B. M. Rubayet Bostami and Shilpi Islam: Supported to conduct the experiment.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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