Feeding of processed vegetable wastes to bulls and its potential environmental benefit

Nani G. Das,$a,*, Khan S. Huque$,$1, Sardar M. Amanullah$,$a, Harinder P.S. Makkar$,$b,2

$a$ Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka 1341, Bangladesh
$b$ Livestock Production Systems Branch, Animal Production and Health Division, FAO, 00100 Rome, Italy

**ABSTRACT**

The study was conducted with the objectives to quantify year round availability of different vegetables waste (VW) in a wholesale market and to determine the inclusion level of a processed VW (VWP) in the diets of bulls. The daily VW biomass availability at Kawran bazaar, Dhaka, Bangladesh was quantified by weighing the vegetable supply and their wastes by visiting 2 days in a week. Concurrently, VW of cucumber, bitter gourd, spotted gourd, brinjal, pumpkin, potato, tomato, ladies finger, and snake gourd representing 0.21, 0.18, 0.16, 0.09, 0.07, 0.06, 0.03, and 0.02 as fresh fractions, respectively were blended, dried and stored while adding rice polish and common salt at 200 and 20 g/kg DM, respectively; it was tested in bulls as an ingredient of concentrate mixture. Four dietary groups, each of 6 bulls, with initial average live weight (LW) of 85.47 ± 17 kg, were fed fresh German grass (Echinochloa polystachya) ad libitum supplemented with 4 different concentrates containing 0, 10%, 20% and 30% VWP at the rate of 1% of LW for 89 days. The availability of VW biomass of the market was 42.51 t/d and recycling of them as feed, instead of using landfills, might reduce annual methane emission by 0.43 Gg. The inclusion of VWP in the diet up to 9.7% of DM, or 0.30% of LW of bulls showed no significant effect on the DM intake, digestibility, growth performance and health status of bulls. The dietary DM intake represented 3.10%, 3.09%, 3.20% and 3.14% of LW resulting in daily gain of 302, 300, 312 and 344 g, respectively. The digestibility of DM of diets was 56.9%, 62.8%, 62.8% and 63.4%, respectively. It was concluded that VWP may be included at a level of 9.7% of the diet (DM basis) or 0.30% of LW of bulls.

1. Introduction

The annual global food loss is about $1.3 \times 10^8$ t which is equal to about 33% of its production (Fox, 2013). This waste, when used as landfill, produces greenhouse gases by anaerobic fermentation for years. Landfills were the third largest anthropogenic source of methane in 2010 which accounted 11% of estimated global methane emissions or nearly $7.99 \times 10^8$ t CO$_2$ equivalents (U.S. EPA, 2011). In Bangladesh, urban households produce about 4.87 $\times$ 10$^8$ t of wastes per year consisting of 67.65% food and vegetable wastes (VW) that are disposed as landfills. Recycling and reuse of this VW, instead of dumping into landfills, may contribute to reduce environment pollution.

The production of bio-fertilizer and energy (biogas, biodiesel and electricity) from managing food and VW are some of the alternatives that have been used to reduce its long term impacts on the environment (Suthar, 2009; Kamaraj, 2008 and Hossain and Fazlity, 2010). Moreover, the potentiality of VW as feed for farm animals has been reported in some studies. Angulo et al. (2012a) reported that fruit and VW from marketplace may contain 9.1% to 11.6% crude protein (CP), 32% to 43% neutral detergent fibre (NDF),
14.7 to 15.9 MJ/kg DM metabolizable energy (ME) with the rumen degradability of 82.94% to 89.82% at 24 h of incubation. Supplementation of lactating diets with 1.0 kg concentrate daily containing 18.0% fruit and VW from marketplace was also reported to produce milk with a higher proportion of \(\alpha\)-linolenic acid and cis-9, trans-11 conjugated linoleic acid (CLA) without affecting daily milk yield (Angulo et al., 2012b). In Bangladesh, the VW from both households and marketplace was reported to be safe, because levels of commonly used pesticides (metalaxyl, carbofuran, organochlorine and organophosphorus pesticides), heavy metals (lead and total chromium) and total aflatoxins were below the threshold that could cause adverse effects. Moreover, the nutritional parameters of VW were equal to some commonly used feed ingredients, such as wheat bran and groundnut hay. They contained 14% to 17% CP, 37% to 41% NDF, 63% to 67% total digestible nutrients (TDN) with rumen degradability of 80% to 85% at 72 h of incubation, respectively (Das et al., 2018). Concurrently, a 34-day feeding trial in growing bulls fed processed VW (VWP) at 27% of the diet or 0.76% of their live weights (LW) resulted in high blood creatinine and low dietary intake without affecting digestibility (Das et al., 2018). The present study was, therefore, undertaken in order to quantify year round VW biomass availability at a marketplace, determine their physical and chemical composition, estimate the potential environmental benefits of recycling VW as feed and to determine the optimum inclusion level of VWP in the diet of growing bulls.

2. Materials and methods

2.1. Quantification of vegetable wastes

Being one of the biggest 7-day wholesale markets in Dhaka, Bangladesh, Kawran bazaar was selected for studying VW biomass availability in summer (April to June), rainy (July to October) and winter seasons (November to February) by visiting 2 different days in a week, starting from March, 2016 to February, 2017.

The market supply of different vegetables and the total of all marketed vegetables were collected from the warehouse of all the suppliers/transporters of the market early in the morning. In order to quantify total market waste, the trucks carrying the wastes were counted, while the wastes were being removed early in the morning. The total waste was calculated by multiplying the number of trucks and their capacity (t/d). The market waste was consisted of VW and their packaging and transporting materials. Therefore, the total market waste from 3 of the randomly selected trucks was separated into 5 different constituents, such as, VW, straw and tree leaves, paper and cardboard, wood, and plastic and polythene, and weighed. At the same time, VW were also divided into major vegetable types and weighed. The average weight of them was multiplied by the number of trucks in order to get their daily total biomass. Thereby, market availability of total VW, major vegetables contributing to total VW and non-vegetable constituents were calculated.

The vegetable marketing chain of this market was consisted of 5 consecutive groups: farmers or producers, suppliers or transporters who collect vegetable and transport to wholesalers, wholesalers who sell to retailers, and the retailers who sell to consumers. Waste of vegetables was also quantified during transportation, at wholesale storage places and at retail shop levels. During transportation and wholesale levels, the weight of different VW was measured. Similarly, a total of 30 retailers of various selling capacity was randomly visited, the types of vegetables they used to sell and the wastes made were recorded to quantify percent of vegetable wasted at retail shop level. Thus, the percent waste of different vegetables during transport, at wholesale storage and at retail shops were quantified.

2.2. Collection and preparation of vegetable waste samples

Freshly collected samples of VW were chopped into 1-cm pieces, mixed thoroughly and representative samples were used for the determination of DM contents. A portion of samples was dried, milled by passing through a 1-mm screen and stored in air tight sampling bag before sending them to laboratory. Samples in triplicate of bean, brinjal, bitter gourd, cucumber, cabbage, spotted gourd, cauliflower, snake gourd, tomato, sweet gourd and potatoes collected in 3 different days of each season were analyzed for their chemical compositions.

2.3. Calculation of methane emission

Annual methane emissions for the disposal of total market waste into landfills and that from cattle by considering VW portion as feed were calculated. The methane emission for the disposal of total wastes into landfills was calculated according to IPCC (1996) by following Tier 1 approach. The following equation was used for calculation:

\[
\text{Methane emission (Gg/yr) = VWT} \times \text{VWF} \times \text{MCF} \times \text{DOC} \times F \times (16/12 - R) \times (1 - \text{OX}),
\]

where VWT, total amount of VW calculated (Gg/yr); VWF, fraction of VW disposed in landfills (considered 100% for calculation); MCF, methane correction factor (0.4, default value); DOC, degradable organic carbon; DOC\(_{	ext{c}}\), fraction of DOC dissimilated (0.77, default value); F, fraction of methane in landfill gas (0.5, default value); R, recovery of methane from landfills (0 for Bangladesh); OX, oxidation factor (0, default value). The DOC was calculated from the physical composition of total market wastes using the following equation:

\[
\text{DOC} = 0.4A + 0.17B + 0.15C + 0.3D,
\]

where A, B, C and D represents the percent amount of paper and cardboards, straw and leaves, vegetable wastes, and wood in total market wastes, respectively.

The enteric methane emission from cattle was calculated according to IPCC (2006), using Tier 2 approach, by considering VW as feed, and by calculating digestible DM (%), DDM (%), TDN (%) and gross energy (GE) content according to Rohweder et al., Ball et al., Rohweder et al., and Ball et al., respectively. The following equations were used for calculation (average DM and ADF values of VW were 7.9% and 32.67%, respectively) for the total available VW of the market in the same year:

\[
\text{DM of the available VW (t/d) = VW (t/d) \times DM (\%),}
\]

\[
\text{DDM (\%) = 88.9 - 0.77 \times ADF (\%),}
\]

\[
\text{DDM (t/d) = DM of the available VW (t/d) \times DDM (\%),}
\]

\[
\text{TDN of the VW (\%) = 87.8 - 0.7 \times ADF (\%),}
\]

\[
\text{ME of the VW (MJ/kg DM) = (TDN - 10.2)/5.4,}
\]

\[
\text{GE of the VW (MJ/kg DM) = (ME/0.82)/0.70.}
\]

Total GE of the VW (MJ/d) = GE of the VW (MJ/kg DM) \times DM of the available VW (t/d) \times 1,000,
Enteric methane emission (kg/d) = Total GE of the VW (MJ/d) × 6.5/55.65,

where 6.5 is the default methane conversion factor for cattle and 55.65 is the energy content of 1 kg methane. Finally, results were expressed as Gg/yr (1 Gg = 1,000 t = 10^6 kg).

2.4. Processing of vegetable wastes into feed

Vegetable wastes were processed into feed according to Das et al. (2018). The VW from marketplace was transported in the evening to a processing center at the Animal Research Station of Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka. The VW biomass of marketplace, on fresh basis, was constituted of (as fraction) waste cucumber (0.21), followed by 0.18, 0.17, 0.16, 0.09, 0.07, 0.06, 0.03, and 0.02, respectively of bitter gourd, spotted gourd, brinjal, pumpkin, potato, tomato, ladies finger, and snake gourd during the collection period of summer. The VW, after collection, were cleaned by using a stream of water, and any degraded particles were removed before blending. Rice polish was added as an absorbent during blending to facilitate quick drying at a rate of 200 g/kg DM of VW. At the same time, common salt was added at the rate of 200 g/kg DM of VW. At the same time, common salt was added as an absorbent during blending to improve the palatability and thus ensuring voluntary intake of this feed by the experimental animals. Depending on the intensity of sunlight, the blended biomass was sundried for about 32 to 40 h until the moisture content was reduced to less than 120 g/kg DM, and then stored in plastic buckets. A bulk amount of product, produced from VW, hereafter addressed as a VWP, was used for feeding growing bulls as one of the major feed ingredients of a conventionally mixed concentrate.

2.5. Selection of bulls and their management

Twenty-four indigenous growing Red Chittagong Cattle (RCC) bulls of about 12 to 18 months of age with an average initial LW of 85.47 ± 17 kg were selected and housed in individual crates. They were dewormed by drenching according to the prescribed doses of levamisole hydrochloride and triclabendazole (0.075 and 120 g/kg, a commercial anthelmintic drug, Exdex (NOVARTIS) containing 85.47 ± bulls of about 12 to 18 months of age with an average initial LW of 85.47 ± 17 kg were selected and housed in individual crates. They were dewormed by drenching according to the prescribed doses of levamisole hydrochloride and triclabendazole (0.075 and 120 g/kg, a commercial anthelmintic drug, Exdex (NOVARTIS) containing levamisole hydrochloride and triclabendazole (0.075 and 120 g/kg, respectively). Bulls were divided into 4 equal dietary groups of similar LW and offered experimental diets.

2.6. Experimental diets

Freshly harvested German grass (Echinochloa polystachya) was chopped into 2 to 3 cm pieces and offered ad libitum to all bulls as a basal diet during experimental period. However, bulls of 4 dietary groups were supplemented with 4 different concentrate mixtures containing 0, 10%, 20% and 30% of VWP (DM basis) at the rate of 1% of LW for a period of 89 days, including 7 days of metabolic trial at the end. Both German grass and stipulated concentrate mixtures were offered at morning and evening (08:00 and 16:00) in equal meals. Clean water was supplied ad libitum during the whole trial period. The daily total supply of German grass was always kept 10% higher than the previous day's intake in order to ensure ad libitum intake. All bulls were weighed at 7 days intervals before morning meals in order to calculate daily concentrate requirement and daily gain achieved. The ingredient composition of concentrate mixtures and the chemical composition of both concentrate mixtures and German grass are presented in Tables 1 and 2, respectively. All the concentrate mixtures were isoenenergetic and isonitrogenous.

2.7. Collection of samples

Fresh German grass was harvested, chopped and mixed thoroughly every morning, and 3 representative samples were analyzed for DM contents. For determining chemical composition, about 10 g of dried ground German grass was stored daily in air-tight sample bottles, and at the end of the trial they were mixed thoroughly, sampled and analyzed. Feed refusals were weighed individually; they were mixed thoroughly and sampled for determining DM contents. Daily DM intake from German grass was calculated by deducting DM refused from its supply. Concentrate mixtures were prepared weekly, DM was determined from fresh samples, and representative samples were stored for analyzing chemical composition. Both German grass and concentrate samples were milled and passed through a 1-mm screen before preparing samples for chemical analysis.

During the last 7 days of metabolic trial, dung of each bull, collected every 24 h, was weighed, mixed thoroughly and a representative sample was analyzed for DM content. About 10% of dung sample was stored at −20 °C until analysis. Finally, 7 samples for each bull were thawed, mixed properly, sampled and analyzed for chemical composition. Urine was collected in a plastic bucket containing 250 mL of 10% H2SO4 solution to keep pH below 3. The urine was finally diluted and mixed thoroughly with fresh clean tap water to a fixed volume of 20 L daily and representative sample was collected in a labeled plastic bottle and kept in −20 °C. At the end of collection period, both urine and dung samples of each bull were thawed at room temperature and a composite sample was made for laboratory analysis.

On the last 3 days of trial, blood samples of each bull were collected 2 h after morning meal in serum clot activator tubes (Greiner Bio-One VACUETTE, Austria; 6.0 mL, 13 mm × 100 mm tube), and immediately after collection serum was separated by centrifuging at approximately 2,000 × g for 10 min using a Bench–Top Centrifuge (Type: NF 200, Turkey; http://www.nuvec.com.tr). They were stored at −20 °C in a freezer for subsequent

### Table 1

| Item                  | Levels of VWP in concentrate, % DM |
|-----------------------|------------------------------------|
|                       | 0       | 10      | 20      | 30      |
| Rice polish           | 7       | 4       | 2       | 0       |
| Maize broken          | 13      | 13      | 13      | 11      |
| Wheat bran            | 40      | 35      | 29      | 24      |
| VWP                   | 0       | 10      | 20      | 30      |
| Soybean meal          | 18      | 17      | 17      | 17      |
| Khesari bran          | 18      | 17      | 15      | 14      |
| DCP                   | 2       | 2       | 2       | 2       |
| Common salt           | 2       | 2       | 2       | 2       |
| Total                 | 100     | 100     | 100     | 100     |

DM – dry matter; VWP – processed vegetable waste; DCP – di-calcium phosphate.

### Table 2

| Item                  | German grass | levels of VWP in concentrates, % DM |
|-----------------------|--------------|------------------------------------|
|                       | 0       | 10      | 20      | 30      |
| DM, g/kg fresh        | 203.2   | 882.2   | 885.6   | 875.4   | 887.6   |
| OM                   | 910.8   | 876.0   | 865.8   | 876.6   | 863.0   |
| CP                   | 93.3    | 179.8   | 166.8   | 165.8   | 161.4   |
| NDF                  | 712.6   | 414.7   | 426.6   | 480.6   | 567.3   |
| ADF                  | 333.7   | 287.7   | 244.8   | 229.0   | 254.7   |
| EE                   | 16.30   | 24.40   | 22.30   | 21.30   | 22.20   |

VWP – processed vegetable waste; DM – dry matter; OM – organic matter; CP – crude protein; NDF – neutral detergent fiber; ADF – acid detergent fiber; EE – ether extract.
biochemical analysis. The blood metabolic profiles (blood sugar [BS]; blood urea nitrogen [BUN]; total cholesterol [TC]; triglyceride; low density lipoprotein [LDL]; high density lipoprotein [HDL] and creatinine) and liver function tests (serum glutamic pyruvic transaminase [SGPT]; serum glutamic oxaloacetic transaminase [SGOT]) were performed using the serum sample of each bull.

2.8. Chemical analysis of samples

The chemical composition (DM, OM and CP) of VW samples, feeds, refusals and feces from the feeding trial were analyzed in the animal nutrition laboratory of BLRI (this laboratory participates in the FAO-IAG proficiency testing program) according to AOAC (2004). The NDF and ADF contents were determined according to Ball et al. (2004). The TDN contents of VW were calculated according to Ball et al. (2004). The NDF and ADF contents were determined according to Van Soest et al. (1991) and results were expressed inclusive of ash. The chemical composition in different seasons varied significantly \( (P < 0.01) \). The amounts of total waste in the rainy and winter seasons were similar, but significantly lower than those in summer \( (P < 0.01) \). The year round average of them was 43.10 t/d. Similarly, the rainy and winter seasons had the similar amount of available VW biomass, but it was significantly lower than that in summer \( (P < 0.01) \). The amount of straw and plant leaves in the total market waste, commonly used for transporting different market vegetables, differed significantly \( (P < 0.01) \) in 3 different seasons. The amount of paper and cardboard \( (P < 0.01) \) in the rainy season was significantly higher than that in summer. On average, the availability of VW of the market was 42.51 t/d. Similarly, the calculated percentage of VW in relation to market supply in the rainy and winter were similar, but significantly lower \( (P < 0.01) \) than those in summer, and the year round average was 0.91%. Fig. 1 shows that the average market VW availability differed in different months with maximum of 61.2 t/d in May and minimum of 16.6 t/d in October.

2.9. Analysis of blood biochemical parameters

The metabolic profiles of blood serum were determined using a biochemical analyzer (Screen Master–3000; http://www.medworld.com/) with kits produced by RANDOX (Randox Laboratories Limited, County Antrim, UK). The level of BS was determined according to Chasson et al. (1961). The total waste biomass availability of the market and its physical composition in different seasons varied significantly \( (P < 0.01) \). The amounts of total waste in the rainy and winter seasons were similar, but significantly lower than those in summer \( (P < 0.01) \). The year round average of them was 43.10 t/d. Similarly, the rainy and winter seasons had the similar amount of available VW biomass, but it was significantly lower than that in summer \( (P < 0.01) \). The amount of straw and plant leaves in the total market waste, commonly used for transporting different market vegetables, differed significantly \( (P < 0.01) \) in 3 different seasons. The amount of paper and cardboard \( (P < 0.01) \) in the rainy season was significantly higher than that in summer. On average, the availability of VW of the market was 42.51 t/d. Similarly, the calculated percentage of VW in relation to market supply in the rainy and winter were similar, but significantly lower \( (P < 0.01) \) than those in summer, and the year round average was 0.91%. Fig. 1 shows that the average market VW availability differed in different months with maximum of 61.2 t/d in May and minimum of 16.6 t/d in October.

3. Results and discussion

3.1. Physical composition of market waste

The physical composition of market waste is presented in Table 3. The total waste biomass availability of the market and its physical composition in different seasons varied significantly \( (P < 0.01) \). The amounts of total waste in the rainy and winter seasons were similar, but significantly lower than those in summer \( (P < 0.01) \). The year round average of them was 43.10 t/d. Similarly, the rainy and winter seasons had the similar amount of available VW biomass, but it was significantly lower than that in summer \( (P < 0.01) \). The amount of straw and plant leaves in the total market waste, commonly used for transporting different market vegetables, differed significantly \( (P < 0.01) \) in 3 different seasons. The amount of paper and cardboard \( (P < 0.01) \) in the rainy season was significantly higher than that in summer. On average, the availability of VW of the market was 42.51 t/d. Similarly, the calculated percentage of VW in relation to market supply in the rainy and winter were similar, but significantly lower \( (P < 0.01) \) than those in summer, and the year round average was 0.91%. Fig. 1 shows that the average market VW availability differed in different months with maximum of 61.2 t/d in May and minimum of 16.6 t/d in October.

### Table 3

| Item               | Seasons of the year | Average | SEM  | P-value |
|--------------------|---------------------|---------|------|---------|
|                    | Summer | Rainy | Winter |         |         |
| Total waste        | 52.57\(^a\) | 37.59\(^b\) | 39.16\(^b\) | 43.10 | 11.61 | <0.01 |
| Vegetable waste    | 52.05\(^a\) | 36.95\(^b\) | 38.53\(^b\) | 42.51 | 11.56 | <0.01 |
| Non-vegetable waste|        |       |       |         |         |
| Straw and leaves   | 0.23\(^c\) | 0.29\(^b\) | 0.37\(^a\) | 0.30 | 0.07 | <0.01 |
| Paper and card-board| 0.21\(^c\) | 0.25\(^b\) | 0.21\(^b\) | 0.22 | 0.03 | <0.01 |
| Wood               | 0.033\(^a\) | 0.031\(^b\) | 0.026\(^b\) | 0.03 | 0.00 | 0.02 |
| Plastic and polythene| 0.035\(^a\) | 0.036\(^b\) | 0.024\(^b\) | 0.03 | 0.00 | <0.01 |

SEM = standard error of mean. 
\(^{a,b,c}\) Means with different superscripts in the same raw differ significantly \( (P < 0.05) \).

### Table 4

| Item                      | Seasons of the year | Average | SEM  | P-value |
|---------------------------|---------------------|---------|------|---------|
| Total vegetable supply, t/d| 4,894.05\(^a\) | 4,094.10\(^b\) | 4,654.00\(^a\) | 4,547.38 | 536.53 | <0.01 |
| Total vegetable waste, t/d | 52.05\(^a\) | 36.95\(^b\) | 38.53\(^b\) | 42.51 | 11.53 | <0.01 |
| Vegetable waste, %        | 1.01\(^a\) | 0.87\(^b\) | 0.82\(^b\) | 0.91 | 0.17 | <0.01 |

SEM = standard error of mean. 
\(^{a,b}\) Means with different superscripts in the same raw differ significantly \( (P < 0.05) \).

Fig. 1. Year round vegetable waste (t/d) available at Karwan bazaar, Dhaka, Bangladesh.
The annual supply of fresh VW biomass in the market is 15,516 t (calculated as: 42.51 × 365; Table 4). Considering the average DM content of 10.1% (Das et al., 2018), the total DM availability of marketplace VW may be calculated as 1,551 t. If that amount of fodder DM is cultivated, the land requirement for Napier hybrid, maize, Australian Sweet Jumbo or German grass will be 62.0, 74.9, 66.3 or 79.1 ha/yr, respectively (Haque et al., 2017). Therefore, reusing of VW from marketplace as feed for farm animals may help to reduce food-feed competition for cultivable land.

### 3.3. Average share of different vegetables to market vegetable waste biomass

The amount of different VW contributing to market VW biomass in different seasons is presented in Table 5. In summer, the highest amount of waste was found for cucumber, followed by brinjal, spotted gourd, snake gourd, bitter gourd, tomato, ladies finger, sweet gourd, carrot and others. During the rainy season, the waste of spotted gourd was the highest, followed by snake gourd, cucumber, bitter gourd, ladies finger, brinjal, sweet gourd and others. The highest amount of waste was observed for cabbage in winter, followed by cauliflower, cucumber, radish, brinjal, tomato, bean, carrot, sweet gourd and others.

#### 3.4. Production of vegetable waste at different market chains

The proportion of different vegetables in the waste of the marketing chain is presented in Table 6. A highly significant ($P < 0.01$) proportion of waste was found to produce during the wholesale storage of some vegetables, such as brinjal, bitter gourd, cabbage, tomato and radish, followed by retailing shop and transportation. The average range of wholesale waste of the vegetable was 7% to 14%, and it was 5.91% and 3.14% at retailing shop and transportation, respectively. Moreover, the proportion of wastes during the wholesale and retailing was similar, but it differed significantly with that produced during the transport ($P < 0.05$) of some vegetables, such as, sweet gourd, cauliflower, cucumber, carrot and spotted gourd. The range of waste during the wholesale storage and retail shop varied from 5.84% to 9.39%, and it was 3.01% during transport.

However, there was no significant variation in the proportion of wastes produced in different marketing chains for snack gourd, bean, ridge gourd and ladies finger. The proportion of these VW ranged from 2.53% to 4.65%, 3.75% to 7.58% and 3.21% to 6.33%, respectively, during transporting, wholesale storage and retailing shop. Among the vegetables, the highest proportion of total waste was found in case of radish followed by cauliflower, tomato, cucumber, sweet gourd, tomato, bean, spicy gourd and others.

### Table 5

| Item          | Summer | Rainy | Winter |
|---------------|--------|-------|--------|
|               | % VW  | % VW  | % VW   |
| Bean          | 0.00  | 0.00  | 0.65   |
| Bitter gourd  | 4.00  | 3.23  | 2.14   |
| Brinjal       | 4.47  | 2.33  | 2.72   |
| Cabbage       | 3.00  | 5.33  | 5.33   |
| Carrot        | 2.30  | 4.79  | 3.33   |
| Cucumber      | 4.58  | 2.79  | 3.33   |
| Cauliflower   | 1.80  | 1.97  | 2.97   |
| Ladies finger | 3.03  | 2.71  | 7.10   |
| Radish        | 0.90  | 0.43  | 2.82   |
| Snake gourd   | 4.09  | 5.27  | 1.05   |
| Sweet gourd   | 2.47  | 0.77  | 1.43   |
| Tomato        | 3.70  | 7.25  | 2.72   |
| Others        | 19.13 | 12.19 | 12.76  |
| Total         | 52.05 | 36.95 | 38.53  |

SD = standard deviation.

1 Data are presented as means ± SD.

The amount of different VW contributing to VW biomass (% marketed) in different marketing chains is presented in Table 6. In summer, the highest amount of waste was found for cucumber, followed by brinjal, spotted gourd, snake gourd, bitter gourd, tomato, ladies finger, sweet gourd, carrot and others. During the rainy season, the waste of spotted gourd was the highest, followed by snake gourd, cucumber, bitter gourd, ladies finger, brinjal, sweet gourd and others. The highest amount of waste was observed for cabbage in winter, followed by cauliflower, cucumber, radish, brinjal, tomato, bean, carrot, sweet gourd and others.

### Table 6

| Item          | Marketing chains | SEM  | P-value | Total SD |
|---------------|------------------|------|---------|----------|
|               | Transporter | Wholesaler | Retailer |        |
| Brinjal       | 3.10b       | 7.85a     | 5.94b     | 2.51    |
| Bitter gourd  | 3.04b       | 7.01a     | 6.51a     | 1.81    |
| Cabbage       | 2.99b       | 10.89a    | 5.39b     | 3.88    |
| Tomato        | 2.80b       | 10.69a    | 6.34a     | 5.57    |
| Radish        | 3.77b       | 14.06a    | 5.38b     | 3.58    |
| Sweet gourd   | 2.45b       | 6.89a     | 5.91a     | 3.43    |
| Cauliflower   | 3.65b       | 9.39a     | 7.76ab    | 3.62    |
| Cucumber      | 2.78b       | 5.87a     | 5.87a     | 2.95    |
| Carrot        | 2.53b       | 7.78b     | 5.84ab    | 2.87    |
| Spotted gourd | 3.65b       | 6.52a     | 7.22a     | 2.59    |
| Snack gourd   | 4.65        | 7.58      | 5.90      | 3.71    |
| Bean          | 2.54        | 4.01      | 3.21      | 1.66    |
| Ridge gourd   | 2.53        | 3.75      | 4.97      | 2.33    |
| Ladies finger | 4.11        | 6.63      | 6.33      | 3.66    |

SEM = standard error of mean; SD = standard deviation.

a,b,c Means with different superscripts in the same raw differ significantly ($P < 0.05$).

1 Data are presented as means ± SD.
cabbage, snack gourd, spotted gourd, ladies finger, brinjal, bitter gourd, carrot, sweet gourd, cucumber, ridge gourd and bean.

3.5. Chemical composition of different vegetable wastes

The chemical composition of some individual VW is presented in Table 7. The DM content ranged from 4.0% to 17.2% of fresh weight with an average of 7.9%. Among the vegetables, potato and sweet gourd had the lowest CP content, whereas that of other vegetables ranged from 17.3% in brinjal to 27.0% in cauliflower. The values of NDF and ADF contents of the samples ranged from 33.7% in brinjal to 63.4% in cauliflower. The rumen enteric methane emission, if the VW biomass is processed as feed and fed to cattle, may produce only 0.06 Gg of methane emission from total market wastes used as landfills. The bene

3.6. Environmental pollution

The annual methane emission from the market waste at Kawran bazaar when disposed into landfills was lower when compared with the rumen enteric methane emission, if the VW biomass is processed as feed and fed to cattle. The benefit of recycling VW as cattle feed in terms of methane emission reduction is presented in Table 8. It was found that the calculated amount of annual methane emission from total market wastes used as landfills was 0.49 Gg. When compared with disposal into landfills, when the VW biomass is processed as feed and fed to cattle, it may produce only 0.06 Gg rumen enteric methane. Therefore, the recycling of available VW at Kawran bazaar into feed may contribute to reduce methane emission by 0.43 Gg/yr (87.64%).

3.7. Dietary intake and live weight gain of bulls

The intake of nutrients and LW gain of bulls are presented in Table 9. There was no significant effect of replacing conventional concentrates with up to 30% VWP on the dietary DM and nutrient intake of bulls. The DM intake from German grass and concentrate in 0, 10%, 20% and 30% VWP groups was 2.07, 2.03, 2.12 and 2.19 kg/d, and 0.96, 1.00, 0.98 and 1.01 kg/d, respectively, which resulted in total dietary DM intake of 3.03, 3.03, 3.09 and 3.2 kg/d, respectively. The dietary DM intake, therefore, represented 3.10%, 3.09%, 3.20% and 3.14% of average LW of bulls. The daily DMI from

Table 7

| Item                  | Chemical composition, % DM | OM  | CP  | NDF | ADF | TDN |
|-----------------------|----------------------------|-----|-----|-----|-----|-----|
| Bean                  | 92.0 ± 0.3                 | 22.3±4.1 | 45.1±17.4 | 35.8±5.6 | 62.9±3.9 |
| Bitter gourd          | 87.6±5.3                   | 18.8±1.7 | 54.1±5.5  | 41.1±6.5 | 58.9±4.2 |
| Brinjal               | 90.6±3.4                   | 17.2±0.9 | 47.2±8.0  | 42.1±4.8 | 58.4±3.4 |
| Cabbage               | 86.4±2.2                   | 17.3±0.7 | 33.7±15.5 | 20.9±1.6 | 73.2±1.1 |
| Cucumber              | 90.1±2.5                   | 20.1±1.3 | 42.7±3.7  | 37.5±3.8 | 61.8±2.6 |
| Cauliflower           | 84.6±3.9                   | 27.0±1.0 | 58.4±0.4  | 30.4±6.3 | 66.5±4.4 |
| Potato                | 90.8±6.4                   | 10.6±0.5 | 35.1±28.7 | 10.0±0.8 | 81.1±0.9 |
| Snake gourd           | 95.1±1.1                   | 18.4±0.9 | 48.0±6.8  | 37.7±4.6 | 61.4±3.2 |
| Spotted gourd         | 94.7±1.6                   | 19.4±1.2 | 61.3±18   | 35.9±9.7 | 62.6±6.3 |
| Sweet gourd           | 93.2±2.6                   | 9.4±1.2  | 43.1±9.2  | 31.2±8.1 | 66.0±5.6 |
| Tomato                | 91.4±1.2                   | 20.0±1.1 | 50.3±3.0  | 36.5±3.0 | 62.0±2.1 |

DM — dry matter; OM — organic matter; CP — crude protein; NDF — neutral detergent fiber; ADF — acid detergent fiber; TDN — total digestible nutrients.

1 Data are presented as means ± SD.

Table 8

Reduction of methane emission by recycling vegetable waste into feed.

| Item                                    | Amount 1 |
|-----------------------------------------|----------|
| Methane emission from landfill sites of | 0.49 ± 0.15 |
| market waste, Gg/yr                     |          |
| Rumen enteric methane emission for feeding | 0.06 ± 0.02 |
| processed vegetable waste, Gg           |          |
| Reduction of methane emission, Gg/yr    | 0.43 ± 0.13 |
| Methane emission reduction efficiency, % | 87.64±0.14 |

SD — standard deviation.

1 Data are presented as means ± SD.

Table 9

Intake of nutrients and live weight (LW) gain of bulls.

| Item                                    | VWP in concentrate, % DM | SEM  | P—value |
|-----------------------------------------|--------------------------|------|---------|
| DM from German grass, kg/d              | 2.07 0.07 2.12 0.22     | 0.22 | 0.614   |
| DM from concentrate, kg/d               | 0.96 1.00 0.98 1.01     | 0.20 | 0.970   |
| Dietary DM, kg/d                        | 3.03 3.03 3.09 3.2      | 0.41 | 0.866   |
| Dietary DM, % LW                       | 3.10 3.09 3.20 3.14     | 0.27 | 0.686   |
| DM from concentrate, % LW               | 0.97 1.01 1.00 0.98     | 0.04 | 0.497   |
| DM from German grass, % LW              | 2.16 2.08 2.21 2.16     | 0.26 | 0.749   |
| DM, g/kg Wt.25                         | 98.97 100.99 99.45 84.52 | 0.664 |
| OM, kg/d                               | 2.79 2.71 2.78 2.87     | 0.36 | 0.874   |
| CP, g/d                                | 365.356.359.368.527.98  | 0.982 |
| NDF, kg/d                              | 1.87 1.87 1.98 2.13     | 0.25 | 0.238   |
| ADF, kg/d                              | 0.97 0.92 0.93 0.99     | 0.12 | 0.744   |
| Initial LW, kg                         | 84.83 85.86 84.82 87.88 | 18.9 | 0.986   |
| Final LW, kg/d                         | 111.12 112.44 119.18 118.44 | 21.49 | 0.617   |
| Total gain, kg                         | 26.9 26.7 27.8 30.6     | 6.95 | 0.499   |
| LW gain, g/d                           | 302.300.312.344.783.18 | 78.13| 0.499   |

VWP — processed vegetable waste; DM — dry matter; SEM — standard error of the mean; OM — organic matter; CP — crude protein; NDF — neutral detergent fiber; ADF — acid detergent fiber.

Table 10

Digestibility of nutrients (%) of processed vegetable waste (VWP) in concentrate.

| Item                                    | VWP in concentrate, % DM | SEM  | P—value |
|-----------------------------------------|--------------------------|------|---------|
| DM                                      | 56.9 62.8 62.8 63.4     | 5.2  | 0.136   |
| OM                                      | 60.0 65.0 65.4 65.7     | 4.4  | 0.109   |
| CP                                      | 67.1 70.0 69.7 69.2     | 4.6  | 0.689   |
| NDF                                     | 58.3 61.3 64.5 65.2     | 6.8  | 0.308   |
| ADF                                     | 40.7 43.5 43.7 46.0     | 9.4  | 0.810   |

DM — dry matter; SEM — standard error of the mean; OM — organic matter; CP — crude protein; NDF — neutral detergent fiber; ADF — acid detergent fiber.
In nitrogen excretion, fecal and urinary nitrogen excretion and 

\[ \text{DOMR} = \frac{\text{LW}}{0.31/\text{average LW (103 kg)}} \times \frac{\text{DM intake}}{0.31/\text{dietary DMI}} \]

DMI from VWP of that group represented 9.7% of the total dietary 

was 64.2% (Huque et al., 2017), which is a little higher than the 

LW of bulls. The reported digestibility of sole German grass in cattle 

affected by the inclusion of VWP up to 9.7% of the diet or 0.30% of 

of average LW of bulls. Similarly, the replacement of conventional 

concentrate by VWP up to 30%, or inclusion of VWP up to 9.7% of 

diets did not affect the microbial nitrogen yield (g/d) or microbial 

nitrogen yield per kg OM fermented in the rumen (g/kg digestible 

organic matter in the rumen [DOMR]).

### 3.10. Blood biochemical parameters of bulls

The blood biochemical parameters are presented in Table 12. The blood metabolic parameters did not differ significantly among the dietary groups. In case of liver and kidney function tests, SGPT differed significantly (P < 0.05), whereas SGOT and creatinine did not differ significantly among dietary groups containing VWP by 0, 10%, 20% and 30% in concentrate mixture, respectively. The level of SGPT in dietary group containing 0 and 10% VWP in concentrate was similar, but decreased significantly (P < 0.05) with the inclusion of VWP by 20% to 30% in concentrate. These levels are within normal physiological levels of healthy cattle (11 to 40 U/L; Radostitis et al., 2000).

### 4. Conclusion

It may, therefore, be concluded that the available VW at Kawran 
bazaar may be a continuous source of biomass for processing into 
cattle feed, and its daily average availability was 42.5 t. The 
processed VW may replace conventional concentrate by 30% without 
affecting daily gain, dietary intake, digestibility and health status of 
bulls. It may be fed to bulls up to 9.7% of the DM of the diet, or at 
0.30% of LW. The recycling and reuse of daily available VW at 
Kawran bazaar as feed may reduce annual methane emission by 
0.43 Gg and food-feed competition for cultivable land.

### Conflicts of interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work.

### Acknowledgement

We gratefully acknowledge the sincere support of the leading 
wholesalers, vegetable transporters and waste cleaners of Kawran 
bazaar vegetable market during quantification activities.

### References

Angulo J, Liliana M, Sergio AY, Angela MY, Gilberto B, Harold J, Edward V, Tomas V, Jorge G. Nutritional evaluation of fruit and vegetable wastes as feedstuff for 
diets of lactating Holstein cows. J Environ Manag 2012b;95:210–4.

Angulo J, Liliana M, Sergio AY, Angela MY, Gilberto B, Harold J, Edward V, Tomas V, Jorge G. Quantitative and nutritional characterization of fruit and vegetable 

waste from marketplace: a potential use as bovine feedstuff? J Environ Manag 2012a;95:201–9.

AOAC. Official methods of analysis of the association of official analytical chemists 
(AOAC). 20th ed. 2004. Washington DC.

Artiss JD, Zak B. Measurement of cholesterol concentration. In: Rifai N, Warnick GR, 
Dominiczak MH, editors. Handbook of lipoprotein testing. Washington: AACC 
Press; 1997. p. 99–114.

Ball DM, Collins M, Lacefield GD, Martin NP, Mertens DA, Olson KE, Putnam DH, 
Undersander DJM, Wolf W. Understanding forage quality. American Farm. Bu-
reau Federation Publication; 2001. http://pes.uvm.edu/pdpforage/Materials/
ForageQuality/Understanding_Forage_Quality_Ball.pdf. [Accessed 20 March 
2016].

BSTI. Feeds and feeding standards for farm animals and pets. Bangladesh, Bangladesh standards and testing institute (BSTI), Maan Bhalan 116/A, Tejgaon 
industrial area, Dhaka-1208. 30. 2008.

Burrin JM, Alberti HG. What is blood glucose: can it be measured? Diabet Med 1990;7(3):190–206.

### Table 11

| Item | VWP in concentrate, % DM | SEM | P - value |
|------|--------------------------|-----|-----------|
| N intake, g/d | 62.22 63.37 62.23 64.05 7.79 0.975 |
| Fecal N, g/d | 20.97 18.51 18.87 19.92 3.95 0.704 |
| Urinary N, g/d | 7.45 7.75 9.00 8.18 0.10 0.071 |
| Total N excretion, g/d | 28.42 26.26 27.87 28.09 4.32 0.827 |
| N balance, g/d | 34.81 36.12 34.36 35.95 5.49 0.931 |
| Microbial N yield, g/d | 33.84 42.30 43.06 39.73 10.23 0.612 |
| Microbial N yield, g/kg DOMR | 18.67 21.77 21.68 19.18 3.98 0.785 |

VWP = processed vegetable waste; SEM = standard error of mean; DOMR = digestible organic matter in the rumen.

### Table 12

| Item | VWP in concentrate, % DM | SEM | P - value |
|------|--------------------------|-----|-----------|
| BS, mmol/L | 4.55 4.28 4.08 3.6 0.61 0.067 |
| BUN, mg/dL | 40.28 39.20 36.17 37.83 4.01 0.321 |
| TC, mg/dL | 76.14 73.40 89.33 79.17 13.27 0.221 |
| Triglyceride, mg/dL | 34.71 30.20 33.50 33.67 10.40 0.899 |
| LDL, mg/dL | 53.14 45.60 66.83 54.50 17.07 0.247 |
| HDL, mg/dL | 16.14 15.60 15.17 16.83 2.73 0.747 |
| Liver and kidney function tests | | | |
| SGPT, U/L | 38.71b 34.00b 21.00a 27.00a 4.99 0.000 |
| SGOT, U/L | 60.85 58.20 43.67 55.67 18.04 0.377 |
| Creatinine, mg/dL | 0.91 0.86 0.95 0.98 0.16 0.634 |

VWP = processed vegetable waste; SEM = standard error of mean; BS = blood sugar; BUN = blood urea nitrogen; TC = total cholesterol; LDL = low density lipo-
protein; HDL = high density lipoprotein; SGPT = serum glutamate pyruvate transaminase; SGOT = serum glutamate oxaloacetate transaminase.

.superscripts in the same raw differ significantly (P < 0.05).

VWP in 30% VWP diet was 0.31 kg (Table 9). Thus, the calculated 
DMI from VWP of that group represented 9.7% of the total dietary 
DM intake (0.31/dietary DMI x 100%; Table 9), or 0.30% of average 
LW [0.31/average LW (103 kg)] x 100%; Table 9), of bulls in 30% VWP 
dietary group. Similar to DM intake, there was no significant dif-
cference in CP, NDF and ADF intakes of bulls. The daily CP intake is 
sufficient for maintaining adequate rumen fermentation (Ferre 
et al., 2007) and preventing the reduction of intake and diges-
tibility (Van Soest, 1994).

There was no significant difference in final LW, and LW gain of 
bulls due to replacement of conventional concentrate with 0, 10%, 
20% and 30% VWP, respectively. According to BSTI (2008), the daily 
requirement of DM and CP of a 100-kg bull with daily gain of 250 to 
500 g/d may range from 2.9 to 3.1 kg and 306 to 379 g, respectively. 
Therefore, the intake of DM and CP of experimental bulls were 
sufficient for maintaining their LW and daily gain.

### 3.8. Digestibility of nutrients

The digestibility of nutrients, as presented in Table 10, was not 
affected by the inclusion of VWP up to 9.7% of the diet or 0.30% of 
LW of bulls. The reported digestibility of sole German grass in cattle was 64.2% (Huque et al., 2017), which is a little higher than the 
average of present study (61.4%).

### 3.9. Nitrogen balance and microbial protein yield

The nitrogen balance of bulls and their microbial protein yield 
are presented in Table 11. It was found that nitrogen balance in all 
dietary groups was positive, and there was no significant difference 
in nitrogen excretion, fecal and urinary nitrogen excretion and 
nitrogen balance due to the inclusion of VWP up to 9.7% of diet or 
0.30% of LW of bulls. Similarly, the replacement of conventional 
concentrate by VWP up to 30%, or inclusion of VWP up to 9.7% of 
diets did not affect the microbial nitrogen yield (g/d) or microbial 
nitrogen yield per kg OM fermented in the rumen (g/kg digestible 
organic matter in the rumen [DOMR]).
Chasson AL, Grady HJ, Stanley MA. Determination of creatinine by means of automatic analysis. Am J Clin Pathol 1961;35:83–8.

Das NG, Huque KS, Amanullah SM, Dharmapuri S, Makkar HPS. Study of chemical composition and nutritional values of vegetable wastes in Bangladesh. Vet Anim Sci 2018;5:31–7. https://doi.org/10.1016/j.vas.2018.02.003.

Davis C, Wiggins L, Hersom M. Utilization of cull vegetables as feedstuffs for cattle. IFAS EDRS document. Publication #AN 280. 2012. p. 1–3. http://edis.ifas.ufl.edu/AN280. [Accessed 21 December 2017].

Doumas BT, Watson WA, Biggs HG. Albumin standards and the measurement of serum albumin with Bromocresol green. Clin Chim 1971;31:87–96.

Enayetullah I, Sinha AHMM, Khan SSA. Urban solid waste management of Bangladesh: problems and prospects. Waste concern Technical document. 2006. Fawcett JK, Scott JE. A rapid and precise method for the determination of urea. J Clin Pathol 1960;13:156–9.

Fox T. Global food: waste not, want not. Institution of mechanical engineers. 2013. www.imeche.org/docs/default-source/reports/Global_Food_Report.pdf?sfvrsn=0.

Freer M, Dove H, Nolan JV. Nutrient requirements of domesticated ruminants. Collingwood, Australia: CSIRO publishing: 2007.

Grove TH. Effect of reagent pH on the determination of HDL cholesterol by precipitation with sodium phosphotungstate-magnesium. Clin Chim 1979;25(4):560–4.

Hossain ABMS, Fazliny AR. Creation of alternative energy by bio-ethanol production from pineapple waste and the usage of its properties for engine. Afr J Microbiol Res 2010;4(9):812–9.

Huque KS, Roy BK, Das NG. Biometrical ranking of fodder crops for sustainable Livestock and clean air production. Asian J Agric Food Sci 2017;05(3):134–43.

IPCC. Guidelines for national greenhouse gas inventories. Chapter 10. 2006. Emissions from livestock and manure management. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf.

Kamaraj S. Biogas based power generation from fruit and vegetable waste through bi-phasic digestion. Nanotech Symposia. Boston. Junio. 2008. p. 1–5.

Meiattini F, Prencipe L, Bardelli F, Giannini G, Tarli P. The 4-hydroxybenzoate/4-amino phenazone chromogenic system used in the enzymic determination of serum cholesterol. Clin Chim Acta 1978;24(12):2161–5.

Moran J. Tropical dairy farming. Feeding management for small holder dairy farmers in the humid tropics. Landlinks Press. 2005. 150 Oxford St (PO Box 1119), Collingwood VIC 3066, Australia. ISBN-13: 978–0643091238.

Murray R. Lactate dehydrogenase. In: Kaplan A, Rubaltelli FF, Hammerman C, editors. Clinical chemistry. The C.V. Mosby Co. St Louis. Toronto. Princeton1154; 1984. p. 162–71.

Radostitis OM, Gay CC, Blood DC, Hinchcliff KW. Clinical examination farm animals. Veterinary medicine. 9th ed. London: WB Saunders; 2000. p. 1819–22.

Rohwedder DA, Barnes RF, Jorgensen N. Proposed hay grading standards based on laboratory analyses for evaluating quality. J Anim Sci 1978;47:747–59.

Suthar S. Vermicomposting of vegetable-market solid waste using Eisenia fetida: impact of bulking material on earthworm growth and decomposition rate. Ecol Eng 2005;25(3):914–20.

Van Soest PJ. Nutritional ecology of the ruminant. 2nd ed. New York, US: Cornell University Press; 1994. p. 337–54.

Van Soest PJ, Robertson JD, Lewis BA. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharide in relation to animal nutrition. J Dairy Sci 1991;74:3583–97.

Young EG, Conway CF. On the estimation of allantoin by the Rimini-Schryver reaction. J Biol Chem 1942;142:839–52.