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Original Research Article

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

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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, 0.17, 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 1.3×10^9 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 7.99×10^8 t CO_2 equivalents (U.S. EPA, 2011). In Bangladesh, urban households produce about 4.87×10^6 t of wastes per year consisting of 67.65% food and vegetable wastes (VW) that produces about 2.19×10^6 t CO_2 equivalent greenhouse gases per year when disposed as landfills (Enayetullah et al., 2006). 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 Fazliny, 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),

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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 α-linolenic acid and cis-9, trans-11conjugated 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 cardboards, 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:

$$\text{Methane emission (Gg/yr)} = VW_T \times VW_F \times MCF \times DOC \times DOC_F \times F \times (16/12 - R) \times (1 - OX),$$

where VW_T, total amount of VW calculated (Gg/yr); VW_F, fraction of VW disposed in landfills (considered 100% for calculation); MCF, methane correction factor (0.4, default value); DOC, degradable organic carbon; DOC_F, 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:

$$DOC = 0.4A + 0.17B + 0.15C + 0.3D,$$

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. (1978), Ball et al. (2001) and Moran (2005), 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:

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

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

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

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

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

$$\text{GE of the VW (MJ/kg DM)} = (\text{ME}/0.82)/0.70,$$

$$\text{Total GE of the VW (MJ/d)} = \text{GE of the VW (MJ/kg DM)} \times \text{DM of the available VW (t/d)} \times 1{,}000,$$

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 20 g/kg DM of VWP so as 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 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 isoenergetic and isonitrogenous.

Table 1
The ingredient composition of concentrate mixture (g/100 g DM, DM basis).

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
Chemical composition (g/kg DM) of the diets.

Item	German grass	levels of VWP in concentrates, % DM			
		0	10	20	30
DM, g/kg fresh	203.2	883.2	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 .

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% H_2SO_4 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.nuve.com.tr). They were stored at −20 °C in a freezer for subsequent 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 Van Soest et al. (1991) and results were expressed inclusive of ash. The TDN contents of VW were calculated according to Ball et al. (2001). All the samples were analyzed in duplicate. Microbial protein yield was calculated by calculating urinary excretion of purine derivatives (PD) according to the colorimetric method described by Young and Conway (1942).

2.9. Analysis of blood biochemical parameters

The metabolic profiles of blood serum were determined using a biochemical analyzer (Screen Master–3000; http://www.medwow.com/) with kits produced by RANDOX (Randox Laboratories Limited, County Antrim, UK). The level of BS was determined according to Burrin and Alberti (1990). Blood urea nitrogen was determined according to Fawcett and Scott (1960). The levels of TC and triglyceride were analyzed according to Meiattini et al. (1978) and Artiss and Zak (1997), respectively. The serum LDL and HDL were determined according to Friedewald et al. (1972) and Grove (1979), respectively. The serum activities of SGPT and SGOT were measured using methods described by Doumas et al. (1971) and Murray (1984), respectively. Serum creatinine was measured according to Chasson et al. (1961).

2.10. Statistical analysis

Data was subjected to one-way ANOVA using general linear model (GLM) procedure of a computer package program - SPSS 11.5. The significance was determined at $P \leq 0.05$ level. Standard deviation (SD) and arithmetic mean values of VW biomass in different seasons and their chemical compositions were calculated.

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 card-board ($P < 0.01$) in the rainy season was significantly higher than that in other seasons. The daily average quantity of wood in total market waste differed significantly ($P < 0.01$) in different seasons; the average amount of plastic and polythene in total waste was 0.03 t/d, however, it was significantly ($P < 0.01$) higher in the summer and rainy seasons than that in the winter. Among all the constituents of total market wastes, the VW biomass represented the highest amount, representing 98.63%.

Table 3
Physical composition (t/d) of total market wastes.

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^b	0.25^a	0.21^b	0.22	0.03	<0.01
Wood	0.033^a	0.031^{ab}	0.026^b	0.03	0.00	0.02
Plastic and polythene	0.035^a	0.036^a	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 ($P < 0.05$).

3.2. Daily market supply and waste of vegetable

The daily market supply and waste biomass of vegetable in different seasons of a year are presented in Table 4. The daily average market supply of vegetable in the summer and winter seasons were significantly higher ($P < 0.01$) than those in rainy season. The availability of VW during the rainy and winter seasons was similar, but significantly lower ($P < 0.01$) 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 4
The amount of vegetable supply and waste produced.

Item	Seasons of the year			Average	SEM	*P*-value
	Summer	Rainy	Winter			
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 ($P < 0.05$).

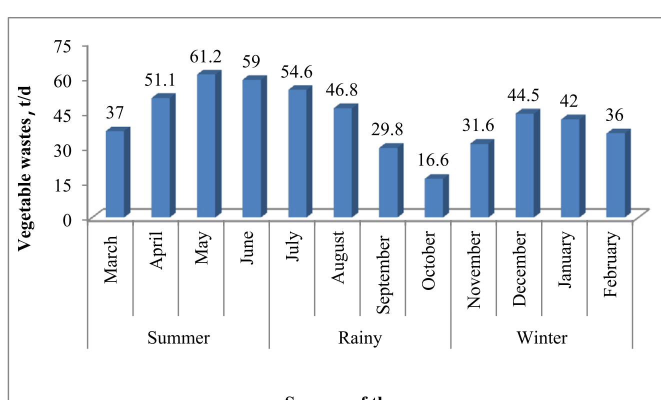

Fig. 1. Year round vegetable waste (t/d) available at Karwan bazaar, Dhaka, Bangladesh.

Table 5
The amount of different vegetable waste (VW) contributing to VW biomass.[1]

Item	Summer		Rainy		Winter	
	t/d	% VW	t/d	% VW	t/d	% VW
Bean	–	–	–	–	2.14 ± 0.53	5.50 ± 0.58
Bitter gourd	4.00 ± 0.99	7.75 ± 1.26	3.23 ± 1.42	9.53 ± 1.33	–	–
Brinjal	4.47 ± 1.04	8.58 ± 0.68	2.33 ± 1.24	5.33 ± 1.58	2.72 ± 0.66	7.00 ± 0.82
Cabbage	–	–	–	–	5.33 ± 0.96	13.78 ± 0.52
Carrot	2.30 ± 0.31	4.50 ± 0.58	–	–	1.64 ± 0.56	4.18 ± 0.89
Cucumber	4.58 ± 0.81	8.88 ± 0.63	4.79 ± 2.07	13.83 ± 1.59	2.95 ± 0.44	7.70 ± 0.87
Cauliflower	–	–	–	–	4.40 ± 1.04	11.35 ± 1.85
Ladies finger	3.03 ± 0.99	5.75 ± 0.96	2.71 ± 1.31	7.10 ± 0.66	–	–
Radish	–	–	–	–	2.82 ± 0.84	7.25 ± 1.71
Snake gourd	4.09 ± 1.28	7.75 ± 0.96	5.27 ± 2.35	15.05 ± 1.46	–	–
Spotted gourd	4.29 ± 1.29	8.13 ± 1.03	5.66 ± 2.77	15.03 ± 0.82	–	–
Sweet gourd	2.47 ± 0.62	4.75 ± 0.50	0.77 ± 0.70	1.43 ± 1.34	1.05 ± 0.21	2.75 ± 0.50
Tomato	3.70 ± 0.59	7.25 ± 1.26	–	–	2.72 ± 0.66	7.00 ± 0.82
Others	19.13 ± 3.95	36.68 ± 0.93	12.19 ± 5.73	32.73 ± 0.98	12.76 ± 0.84	33.50 ± 3.92
Total	52.05	100	36.95	100	38.53	100

SD = standard deviation.
[1] Data are presented as means ± SD.

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 (Huque 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,

Table 6
Waste of some vegetables in different marketing chains (% marketed).

Item	Marketing chains			SEM	*P*-value	Total[1]
	Transporter	Wholesaler	Retailer			
Brinjal	3.10^{c}	7.85^{a}	5.94^{b}	2.51	0.000	16.9 ± 4.67
Bitter gourd	3.04^{b}	7.01^{a}	6.51^{a}	1.81	0.000	16.6 ± 4.00
Cabbage	2.99^{c}	10.89^{a}	5.39^{b}	3.88	0.004	19.3 ± 7.22
Tomato	2.80^{c}	10.69^{a}	6.34^{b}	5.57	0.006	19.8 ± 12.02
Radish	3.77^{c}	14.06^{a}	5.38^{b}	3.58	0.000	23.2 ± 6.29
Sweet gourd	2.45^{b}	6.89^{a}	5.91^{a}	3.43	0.029	15.3 ± 7.01
Cauliflower	3.65^{b}	9.39^{a}	7.76^{ab}	3.62	0.040	20.8 ± 9.65
Cucumber	2.78^{b}	5.87^{a}	5.87^{a}	2.95	0.020	14.5 ± 6.40
Carrot	2.53^{b}	7.78^{a}	5.84^{ab}	2.87	0.040	16.2 ± 6.63
Spotted gourd	3.65^{b}	6.52^{a}	7.22^{a}	2.59	0.011	17.4 ± 6.71
Snack gourd	4.65	7.58	5.90	3.71	0.170	18.2 ± 7.29
Bean	2.54	4.01	3.21	1.66	0.282	9.8 ± 2.75
Ridge gourd	2.53	3.75	4.97	2.33	0.292	11.3 ± 4.10
Ladies finger	4.11	6.63	6.33	3.66	0.341	17.0 ± 9.26

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.

Table 7
Chemical composition of some vegetable wastes[1].

Item	DM, % fresh	Chemical composition, % DM				
		OM	CP	NDF	ADF	TDN
Bean	9.27 ± 0.2	92.0 ± 0.3	22.3 ± 4.1	45.1 ± 17.4	35.8 ± 5.6	62.9 ± 3.9
Bitter gourd	6.0 ± 1.4	87.6 ± 5.3	18.8 ± 1.7	54.1 ± 5.5	41.1 ± 6.5	58.9 ± 4.2
Brinjal	7.85 ± 1.4	90.6 ± 3.4	17.2 ± 0.9	47.2 ± 8.0	42.1 ± 4.8	58.4 ± 3.4
Cabbage	9.97 ± 2.8	86.4 ± 2.2	17.3 ± 0.7	33.7 ± 15.5	20.9 ± 1.6	73.2 ± 1.1
Cucumber	4.0 ± 0.8	90.1 ± 2.5	20.1 ± 1.3	42.7 ± 3.7	37.5 ± 3.8	61.6 ± 2.6
Cauliflower	10.4 ± 3.6	84.6 ± 3.9	27.0 ± 1.0	58.4 ± 0.4	30.4 ± 6.3	66.6 ± 4.4
Potato	17.2 ± 3.2	90.8 ± 6.4	10.6 ± 0.5	35.1 ± 28.7	10.0 ± 0.8	81.1 ± 0.9
Snake gourd	4.3 ± 1.0	95.1 ± 1.1	18.4 ± 0.9	48.0 ± 6.8	37.7 ± 4.6	61.4 ± 3.2
Spotted gourd	7.7 ± 2.0	94.7 ± 1.6	19.4 ± 1.2	61.3 ± 1.8	35.9 ± 9.7	62.6 ± 6.3
Sweet gourd	5.4 ± 2.3	93.2 ± 2.6	9.4 ± 1.2	43.1 ± 9.2	31.2 ± 8.1	66.0 ± 5.6
Tomato	5.2 ± 0.4	91.4 ± 1.2	20.0 ± 1.1	50.3 ± 3.0	36.9 ± 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.

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 cabbage to 61.3% in spotted gourd, and 10.0% in potato to 42.1% in brinjal with the average of 46.8% and 32.7%, respectively. The TDN content of the vegetable ranged from 58.4% in brinjal to 81.1% in potato, with an average of 65.0%. The chemical composition of most of the vegetables is comparable to those reported by Davis et al. (2012).

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%).

Table 8
Reduction of methane emission by recycling vegetable waste into feed.

Item	Amount[1]
Methane emission from landfill sites of market waste, Gg/yr	0.49 ± 0.15
Rumen enteric methane emission for feeding processed vegetable waste, Gg	0.06 ± 0.02
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.

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 9
Intake of nutrients and live weight (LW) gain of bulls.

Item	VWP in concentrate, % DM				SEM	*P*–value
	0	10	20	30		
DM from German grass, kg/d	2.07	2.03	2.12	2.19	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 $W^{0.75}$	98	97	100	99	4.52	0.664
OM, kg/d	2.79	2.71	2.78	2.87	0.36	0.874
CP, g/d	365	356	359	368	52.79	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	84.3	85.6	84.2	87.8	18.9	0.986
Final LW, kg/d	111.2	112.4	111.9	118.4	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	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
	0	10	20	30		
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.

Table 11
Nitrogen (N) balance and microbial N yield.

Item	VWP in concentrate, % DM				SEM	*P* -value
	0	10	20	30		
N intake, g/d	63.22	62.37	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
Blood biochemical parameters of bulls.

Item	VWP in concentrate, % DM				SEM	*P* -value
	0	10	20	30		
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	38.71[b]	34.00[b]	21.00[a]	27.00[a]	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 lipoprotein; HDL = high density lipoprotein; SGPT = serum glutamate pyruvate transaminase; SGOT = serum glutamate oxaloacetate transaminase.
[a,b] Different 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 × 100%; Table 9), or 0.30% of average LW [0.31/average LW (103 kg) × 100%; Table 9], of bulls in 30% VWP dietary group. Similar to DM intake, there was no significant difference in CP, NDF and ADF intakes of bulls. The daily CP intake is sufficient for maintaining adequate rumen fermentation (Freer et al., 2007) and preventing the reduction of intake and digestibility (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]).

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.

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