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Study of chemical composition and nutritional values of vegetable wastes in Bangladesh

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ABSTRACT

The present study was conducted with the objectives of determining the chemical composition and nutritional value of vegetable waste (VW) of households and the marketplace for their suitability as ruminant feed. The crude protein, total digestible nutrients and extent of rumen degradability of dry matter (DM) of VW of households were 140.0 g kg^{-1}, 0.668 and 0.855, respectively; while those of the marketplace were 169.0 g kg^{-1}, 0.633 and 0.80, respectively. The levels of chromium and lead in each respectively, was 13.27 and 1.53 ng kg^{-1}DM; and 31.01 and 5.71 ng kg^{-1}DM. The total aflatoxins in VW of households was 3.08 μg kg^{-1}DM, and undetectable in VW from the marketplace. Considering the chemical composition and safety parameters studied, VW could preliminary be considered as animal feed. The feeding of processed marketplace VW (VWP) at 275 g kg^{-1}DM of a diet or 0.76% of live weight (LW) to growing bulls, replacing 50% of a concentrate mixture as supplement to a Napier silage diet for a period of 34 days reduced the total DM intake (0.0276 vs 0.0343 LW) without any significant ($P > 0.05$) changes in DM or protein digestibility. Blood urea levels (19.5 vs 23.67 mg dl^{-1}), and serum creatinine levels (1.37 vs 1.08 mg dl^{-1}) differed significantly ($P > 0.05$) between the two groups but were within normal physiological ranges. Therefore, it may be concluded that the level of incorporation of VWP would be less than 50% replacement of the concentrate in the diet. Further research is required to determine optimum inclusion levels in ruminant diets.

1. Introduction

Food loss and wastes are 'lost biomass' during handling from farm to table. The annual per capita food waste (FW) of developed and developing countries at the consumer level was estimated to be 95–115 kg and 6–11 kg, respectively (Gustavsson, Cederberg, Sonesson, van Otterdijk, & Meybeck, 2011). The per capita total annual FW in South and South-East Asia was estimated to be about 125 kg, of which 110 kg was found as losses during production to retailing and the remaining 15 kg loss occur during consumption (Gustavsson et al., 2011), and this is estimated to be 3.29×10^6 tones/year in Bangladesh (Enayetullah, Sinha, & Khan, 2006). The annual food loss across the globe was estimated to be about 1.3–1.6 G tonnes, equivalent to be about one-third of the total global food production, cultivation of this requiring 1.5 G ha of land; and this incurs huge environmental (emits 3.3 G tonnes of CO_2 equivalent greenhouse gases (GHG) per year), social (936.0 billion US$/year) and economic (1055 billion US$/year) costs (FAO, 2014; Fox & Fimeche, 2013; Lundqvist, Fraiture, & Molden, 2008). Moreover, burning of these wastes releases GHG and can cause animal and human health concerns.

Global methane emission from landfills due to FW, next to enteric fermentation and fossil fuel burning, was the third largest anthropogenic source of methane, estimated as 11% of global methane emission or nearly 799 million metric tonnes (MMT) CO_2 equivalent in 2010 (U.S. EPA, 2011). In the USA, China, Russia, Brazil and India, methane emission from landfill was estimated to be 130, 47, 37, 18 and 16 MMT CO_2 equivalent in 2010, respectively (U.S. EPA, 2011). Urban household waste in Bangladesh is estimated to produce about 2.19×10^6 tonnes of CO_2 equivalent GHG per year and pollutes the air (Enayetullah et al., 2006). The recycling of biodegradable FW into

Abbreviations: FW, food wastes; VW, vegetable wastes; VWP, processed vegetable wastes; DM, dry matter; LW, live weight; GHG, greenhouse gases; CP, crude protein; NDF, neutral detergent fiber; ME, metabolizable energy; GE, gross energy; TDN, total digestible nutrients; BS, blood sugar; BUN, blood urea nitrogen; LDL, low density lipoprotein; HDL, high density lipoprotein; SGPT, serum glutamic pyruvic transaminase; SGOT, serum glutamic oxaloacetic transaminase; MTL, maximum tolerable level; DMI, dry matter intake

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organic-fertilizer and energy (biogas, biodiesel and electricity) is an option for using this huge amount of waste (Hossain & Fazliny, 2010; Yang et al., 2016), which may reduce environment pollution.

It was reported that a number of vegetable wastes (VW) including baby corn, cabbage, carrot, cauliflower, cucumber, jackfruit, peas, potato, sweet corn, tomato and radish leaves were found to be rich in energy and protein (more than 20%) (Bakshi, Wadhwa, & Makkar, 2016), and that the supplementation of cow feed with a concentrate containing 18.0% fruit and VW from marketplace produced milk with a higher proportion of α-linolenic acid and cis-9, trans-11*conjugated linoleic acid* (CLA) without affecting daily milk yield (Angulo et al., 2012b). However, good practices for VW in terms of determination of chemical composition, processing and feeding response to farm animals are not fully explored till date.

Meeting the growing demand of food of animal origins and feed for farm animals against the backdrop of disappearing cultivable land every year, increasing food-fuel-feed competition, water deprivation and ongoing climate change may be difficult in the future (FAO, 2011; FAO, 2015). Bangladesh, a land hungry country with per capita cultivable land of only 0.05 ha and experiencing annual loss of over 80 thousand hectares of agricultural land (nearly 1%) to non-agricultural usages (Planning Commission, 2009), has been facing an annual deficiency of about 41.5×10^6 tonnes dry matter (DM), (56.2% of total demand) of livestock feeds (Huque & Sarker, 2014). A similar situation prevailes in many other developing countries (Makkar, 2016). Processing of VW into safe feed, a precondition for production of safe food of animal origin, may increase the feed supply to some extent, and could contribute to reducing food and feed production competitions for land. In a survey to define sustainable animal diets, the respondents gave the highest priority to the need to convert FW to animal feed as an environmental dimension of sustainability (Makkar & Ankers, 2014). Also, it was concluded from an FAO e-conference on 'Food Waste to Animal Feed' that there is an urgent need to convert such wastes to safe animal feed (Thieme & Makkar, 2016). Japan and South Korea are two good current examples, where about 40% of FW are being recycled into animal feed (Thieme & Makkar, 2016).

Quantification of VW biomass and its chemical and nutritional evaluation is necessary to ensure the suitability of VW as a feed. Moreover, climatic and environmental factors favour the entry of key contaminants in the food chain and contribute to mycotoxin production during storage (Boxall et al., 2009; Liu et al., 2013; Strawn et al., 2013). The pollution of soil and water and increasing pesticide use is responsible for the entry of heavy metals (Islam, Jahiruddin, Islam, Alim, & Akhtaruzzaman, 2013) and pesticides into food chain (Rahman, 2013). National MRL in many developing countries including Bangladesh for common contaminants such as heavy metals and pesticides in food and feed are usually not available (published) and domestic producers do not necessarily follow Codex Alimentarius or other international standards. A fuzzy logic model for safety assessment of food waste as a feed material (Chen, Jin, Qiu, & Chen, 2014) includes 34 hygiene and pathogens as potential biological issues, and heavy metals, organic pollutants (Aflatoxin B1, HCB 35 and DDT), and soluble chloride as chemical issues. Therefore, the testing of VWP before they are used as animal feed becomes important to avoid recycling of contaminants through the livestock food chain.

The present study was, therefore, conducted with the objectives of determining the chemical composition, in sacco degradability and key feed safety parameters of VW, developing a processing system of bulk VW from marketplace into feed, and determining the impact on the diet intake and digestibility including blood biochemistry on indigenous growing bulls. The study has wide implications, for both developing and developed countries.

2. Materials and methods

2.1. Collection of VW

The VW output of households were collected from twenty randomly selected households in the residential area of Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka, Bangladesh for a period of two months (April and May, 2015). All households were appraised of the objectives of the work through group discussion, and provided with plastic waste bins for collection of VW separately from other household wastes. The VW of three vegetable marketplaces of Savar suburban area, Dhaka was collected in separate waste bins daily during the same period of time.

2.2. Sample preparation and nutritional evaluation

The collected wastes were processed daily by using a stream of water to remove any dirt, vigorously blended in a power operated blender (rpm: 1400), dried in the sun, milled into small particle with a locally manufactured feed grinder and then preserved into airtight plastic containers. After the end of collection, a representative part of all daily milled samples were taken, mixed thoroughly and further ground in a 'Willy Mill', followed by passing through 1.0 mm screens and then used for laboratory analyses. The vigorous blending of bulk fresh sample, initial grinding for particle size reduction, sub-sampling of daily collection, thorough mixing and then final grinding in the Willy mill and sieving through 1.0 mm screen helped to ensure that the sample for chemical analysis was representative. The fresh DM was determined from the fresh samples according to the AOAC (2004). Sample DM, organic matter (OM) and crude protein (CP) were determined at the animal nutrition laboratory of BLRI, according to the AOAC (2004). A bomb calorimeter (IKAØ Calorimeter System C5003 Control, USA) was used for gross energy (GE) estimation. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined according to Van Soest, Robertson, and Lewis (1991). Total digestible nutrients (TDN) were calculated according to Ball et al. (2001). The rumen degradability of each sample at 0, 8, 16, 24, 48 and 72 h was determined by using four rumen cannulated bulls of the Cattle Research Farm of BLRI, according to Ørskov and McDonald (1979). Duplicate samples of each hour were incubated and an hour of incubation was replicated in four bulls. Thus, a sample of single incubation had eight replications. The VW of household and marketplace were analyzed for heavy metals (lead and chromium), according to BSI (2014); total aflatoxins, according to ISO (2003a); and screened for pesticide residues (12 organochlorine and 52 organophosphorous compounds) by LC-MS/MS using the QUECHERS method according to BSI (2008) at the National Food Safety Laboratory (NFSL), Institute of Public Health (IPH), Dhaka, Bangladesh.

2.3. Production of processed vegetable waste (VWP) from VW

The VW from the marketplace was transported in the evening to a processing center at the Animal Research Station of BLRI. The center had fresh water supply, locally assembled machines for blending and a concrete floor for sun drying the blended biomass. The VW biomass of marketplace, on fresh basis, constituted (as fraction) waste cucumber (0.21), followed by 0.180, 0.17, 0.16, 0.09.0, 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 period of collection. The VW, after collection, was cleaned using a stream of water, and any degraded particles were removed before blending. Depending on the DM content of fresh VW of marketplace, rice polish was added as an absorbent during blending to facilitate quick drying, at a rate of 200 g kg^{-1}DM of processed VW. At the same time, common salt was added at the rate of 20 g kg^{-1}DM of processed VW to improve the palatability, and thus to help ensure voluntary intake of this feed by the experimental animals. The blended biomass was sundried until the moisture content was reduced to < 120 g kg^{-1}DM of biomass and stored in plastic buckets. A bulk amount of the product, thus produced from VW, hereafter addressed a vegetable waste processed (VWP), was used for feeding growing bulls as one of the major feed ingredients of a conventionally mixed concentrate feed.

2.4. Animal feeding trial

Twelve growing bulls of local Red Chittagong Cattle (RCC) of 12 10 18 months of age having an average initial live weight (LW) of 66.7 (± 9.7) kg were divided into two equal groups with similar average LW in each group. The RCC is an indigenous cattle breed of Bangladesh with birth weight of male calf and yearlings of 15.74 and 76.18 kg, respectively (Rabeya, Bhuiyan, Habib, & Hossain, 2009). The bulls of both groups were fed ad libitum Napier silage supplemented with either a conventionally mixed concentrates (C-mix) of rice polish, broken maize, wheat bran, soybean meal, di-calcium phosphate (DCP) and common salt or with a concentrate mixture containing 0.50 VWP on DM basis (VWP-mix) (Table 4). As rice polish was added during processing of VW, therefore, rice polish was also included in C-mix to equalize its effects. Again, diets were made iso-enrgic and iso-protein. The composition of feed ingredients of concentrate mixtures, and the chemical composition of Napier silage and the concentrate mixtures are presented in Tables 4 and 5, respectively. In both treatments, the ratio of Napier silage to concentrate was maintained similar (1:1 on DM basis) throughout the feeding period. The daily allowance of concentrate was divided into two equal parts and supplied at 08:00 and 16:00 coordinated universal time (UTC). The bulls were housed individually and fresh water was available at all times. The bulls were weighed initially and finally at the end of a 34-day trial, which included 24 days of adaptation and 10 days of collection period. Usually, in this kind of animal trial, a period of 14 days of adaptation and 7 days of collection period is used (Ru et al., 2002; Tikama, Mikledb, Vearasilpb, Phatsarab, & Südekuma, 2010). An elongated period, especially in adaptation, was used in this study as the feed was derived from processed waste, and to increase the precision of the results (data derived from the collection period). At the beginning of the trial, bulls were dewormed by drenching according to prescribed doses of Endex (NOVARTIS), a commercial anti-helmenthic drug containing 7.5 mg levamisole hydrochloride and 12 g triclabendazole respectively in 100 g bolus.

2.5. Collection of samples and chemical analysis

The feed supplied and refuse were weighed daily during the whole trial period, and DM of silage and refuse was determined twice a week to adjust dietary composition. During the collection period, feed, refuse and feces were weighed daily and representative fresh samples were stored in a freezer at −20 °C. For laboratory analysis, samples were thawed and mixed thoroughly to make it representative. Representative sub-samples were dried and milled and passed through a 1 mm screen for further analysis. The daily intake of silage was calculated by deducting DM of refuse of silage from the offered DM; the intake of DM via concentrate was added to determine the daily total. Concentrate waste was deducted from the offered amount. The coefficient of digestibility of feed nutrients was calculated by multiplying fractions (ƒ) of a supplied nutrient retained in body [ƒ = (feed nutrient – refuse nutrient – feces nutrient) ÷ (feed nutrient-refuse nutrient)]. The quality and quantity of diet may change the blood metabolites of cattle (Ndlovu et al., 2009). Hence, on the last day of the trial, blood samples from each bull were collected 2 h after the morning meal in serum clot activator tubes (Greiner Bio-One VACUETTE®, Austria; 6.0 mL, 13 × 100 mm tube) and serum was separated by centrifuging at approx. 2000 × g for 10 min using a Bench-Top Centrifuge (Type: NF 200, Turkey; ISO, 2003b; http://www.nuve.com.tr) and stored at −20 °C in a freezer for subsequent biochemical analysis. 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). Blood sugar (BS) was determined according to Burrin and Alberti (1990). Blood urea nitrogen (BUN) was determined according to Fawcett and Scott (1960). The level of total cholesterol (TC) and triglyceride was analyzed according to Meiattini, Prencipe, Bardelli, Giannini, and Tarli (1978) and Artiss et al. (1997), respectively. The serum low-density lipoprotein (LDL) and high-density lipoprotein (HDL) was determined according to Friedewald, Levy, and Fredrickson (1972) and Grove (1979), respectively. The serum activities of serum glutamic pyruvic transaminase (SGPT) and serum glutamic oxaloacetic transaminase (SGOT) were measured using methods described by Doumas, Watson, and Biggs (1971) and Murray et al. (1984), respectively. Serum ceatinine was measured according to Chasson, Grady, and Stanley (1961).

2.6. Statistical analysis

The data on the chemical composition of VW of households and from marketplace, their rumen in sacco DM degradability, levels of heavy metals, aflatoxins and pesticide residues as well as digestibility of feed nutrients and serum biochemical parameters are presented, by calculating the mean and standard error of the mean (SEM). Differences between the values, and the response to differences of feeding VWP-mix were compared by Paired sample *t*-test using SPSS-11.5 software (IBM Corporation, 2013).

3. Results and discussion

3.1. Chemical composition of VW

The chemical composition of VW of households and marketplace is presented in Table 1. The DM content of VW of households (136 g kg^{-1}) was significantly ($P < 0.01$) higher than that of VW of marketplace (101 g kg^{-1}). The NDF of VW of households (370 g kg^{-1}DM) was significantly ($P < 0.05$) lower than that of VW of marketplace (410 g kg^{-1}DM). The ADF (300 vs 350 g kg^{-1}DM), CP (140 vs 169 g kg^{-1}DM), TDN (668 vs 633 g kg^{-1}DM) and GE (15.3 vs 15.2 MJ kg^{-1}DM) contents of the two wastes did not differ significantly ($P > 0.05$). A similar level of NDF (316–434 g kg^{-1}DM) and ADF (251–341 g kg^{-1}DM) of fruit and VW of marketplace of different seasons in Colombia was reported by Angulo et al. (2012a). The CP and GE values reported by them ranged from 90.5 to 116 g kg^{-1}DM, and 14.65–15.85 MJ kg^{-1}DM, respectively and all these values corroborate the values of the present study. The VW of households and marketplace, in terms of CP or cell wall materials (NDF and ADF), were found similar to wheat bran (173, 452 and 134 g kg^{-1}DM, respectively; Oddoye, Amaning-Kwarteng, Fleishcher, & Awotwi, 2002) and groundnut hay (146, 451 and 371 g kg^{-1}DM, respectively; Asaolu, Odeyinka, Akinbamijo, & Sodeinde, 2010).

Table 1
Chemical composition of fresh vegetable waste of households and marketplace sources.

Parameters	VW of households	VW of marketplace	SEM	P- value
DM (g kg^{-1} fresh)	136	101	2.12	< 0.01
OM (g kg^{-1}DM)	850	854	4.91	> 0.05
CP (g kg^{-1}DM)	140	169	8.91	> 0.05
NDF (g kg^{-1}DM)	370	410	6.15	< 0.05
ADF (g kg^{-1}DM)	300	350	17.56	> 0.05
TDN (%)	66.8	63.3	1.25	> 0.05
GE (MJ kg^{-1}DM)	15.3	15.2	0.06	> 0.05

VW, vegetable wastes; SEM, standard error of mean; $P > 0.05$, not significant.

Table 2
In sacco dry matter degradability of vegetable waste of households and marketplace.

Parameters	VW of households	VW of marketplace	SEM	*P* – value
a	0.43	0.25	0.005	< 0.01
b	0.42	0.55	0.004	< 0.01
(a + b)	0.85	0.80	0.004	< 0.01
c (per hour)	0.11	0.04	0.01	< 0.01

VW, vegetable wastes; SEM, standard error of mean; $P > 0.05$, not significant; a, readily degradable coefficient; b, potentially degradable coefficient; (a + b), extent of degradation and c, rate constant, per hour.

3.2. Rumen in sacco degradability of VW

The in sacco DM degradability of VW of households and marketplace is presented in Table 2. The readily degradable coefficient (a, 0.43 vs 0.25), potential degradable coefficient (b, 0.42 vs 0.55) and extent of degradation (a + b, 0.86 vs 0.80) of VW of households and marketplace differed significantly ($P < 0.01$). The rate constant of degradation (c) was significantly ($P < 0.01$) higher for VW of households than for VW of marketplace. The VW of households may contain some cooked cereal particles (e.g., rice, bread, biscuit and cake) which were not quantified, and these might have given higher a or c values for VW of households than for VW of marketplace. It was reported that the rumen DM degradability coefficient (at 24 h of incubation) of fruit and VW of different seasons in Colombia ranged from 0.83 to 0.90 (Angulo et al., 2012a). The coefficient of degradability parameters of a, b and c for wheat bran (Khandakar & Tareque, 1996; Mondal, Walli, & Patra, 2008) ranged from 0.29 to 0.38, 0.44 to 0.60, and 0.072 to 0.09 per hour, respectively which are similar to the values for VW of households or marketplace in the present study. The a and b of VW of households and marketplace were similar to those of groundnut cake (0.46 and 0.42) and soybean meal (0.26 and 0.56), respectively according to Mondal et al. (2008). These results suggest that both VW of households and marketplace are comparable to those of some common concentrate feed ingredients, such as, wheat bran, groundnut cake and soybean meal, with respect to their rumen DM degradability parameters. These feeds may replace one or more dietary ingredients, and thus increasing feed availability, decreasing livestock production cost and improving environment.

3.3. Evaluation for heavy metals, total aflatoxins and pesticide residues in VW

The concentration of some heavy metals (total chromium and lead), total aflatoxins (B1, B2, G1 and G2), and some pesticide residues in VW of households and marketplace are presented in Table 3. The levels of total chromium, lead and total aflatoxins in VW of households were 13.27, 1.53 ng kg^{-1}DM, and 3.08 µg kg^{-1}DM, and they were much below the maximum tolerable level (MTL) of these toxic constituents for cattle. According to NRC (1997), the recommended dietary MTL of chromium and lead for cattle is 100×10^6 ng kg^{-1}DM. The maximum residual level of total aflatoxins, according to NRC (2005), in feed worldwide is 20 µg kg^{-1}DM. Similar to the VW of households, the levels of total chromium (31.01 ng kg^{-1}DM) and lead (5.71 ng kg^{-1}DM) of VW of marketplace were below the dietary MTL for cattle. The aflatoxins in VW of marketplace were below the detectable level. The MTL of total aflatoxins in feed of cattle is 300 µg kg^{-1}DM (FAO, 2004). It may, therefore, be stated that VW from household and marketplace may be safe for feeding to animals considering the above levels of chromium, lead and total aflatoxins.

The presence of pesticide residues was determined by analyzing against a panel of pesticides representing organochlorine and organophosphorus groups (Table 3). The residues of 12 organochlorine and 53 organophosphorus pesticides commonly used in Bangladesh were

Table 3
Heavy metals, total aflatoxins, and pesticide residues of vegetable wastes of households and marketplace.

Parameters	VW of households	VW of marketplace	SEM	*P*- value
Total chromium (ng kg^{-1}DM)	13.27	31.01	0.17	< 0.01
Lead (ng $kgDM^{-1}$)	1.53	5.71	0.55	< 0.01
Total aflatoxins (µg kg^{-1}DM)	3.08	n.d.	–	–
Organochlorine pesticides (µg kg^{-1}DM)	n.d.	n.d.	–	–
Organophosphorus pesticides (µg kg^{-1}DM)	n.d.	n.d.	–	–
Metalaxyl (µg kg^{-1}DM)	5.13	17.53	1.01	< 0.05
Carbofuran (µg kg^{-1}DM)	4.76	9.67	0.62	> 0.05

VW, vegetable wastes; SEM, standard error of mean; $P > 0.05$, not significant; n.d., not detected; Organochlorine pesticides include *α, β,* γ, and *δ* benzene hexachloride; Heptachlor, Aldrin, Heptachlor Epoxide, α and γ Chlordane, α Endosulfan Sulphate, Methoxychlor and Endrin; Organophosphorus pesticides include Methamidophos, Acephate, Ethoprophes, Dimethoate, Diazinon, Methyl Parathion, Fenitrothion, Malathion, Fenthion, Chlorpyrifos, Quinalphos, Methidathion, Fenamiphos, Ethion, Cypermethrin, Propioconazole, Acibenzolar-S-methyl, Boscalid, Carbaryl, Clohianidin, Cyromazine, Dimethomorph, Formetanate HCl, Imazalil, Indoxacarb, Methomyl, Myclobutanil, Omethoate, Piperonylbutoxide, Propamocarb, Pyridaben, Spinosad, Thiabendazole, Thiophanate-methyl, Acetamiprid, Azoxystrobin, Buprofezin, Cymoxanil, Derotophos, Dinotefuran, Etoxazole, Hexythiazox, Imodacioprid, Linuron, Methamidophos, Monocrotophos, Prochloraz, Propargite, Pyraclostrobin, Pyrimethanil, Spiromesifen, Thiamethoxam, Trifloxystrobin.

undetectable in either of the VW samples. However, the residues of metalaxyl ($C_{15}H_{21}NO_4$), a phenylamide fungicide, were detected in both VW of households (5.13 µg kg^{-1}DM) and marketplace (17.53 µg kg^{-1}DM). It was reported by Garg et al. (1992) that metalaxyl ($C_{15}H_{21}NO_4$) residues would generally be transitory or undetected in meat, milk, and eggs, if it was present in feed, and therefore, no maximum residual level in feed was established. The level of the insecticide carbofuran ($C_{12}H_{15}NO_3$) residue in VW of households and marketplace (4.76 vs 9.67 µg kg^{-1}DM) were much below the suggested maximum residual levels in rice straw or fodders (1 mg kg^{-1}DM; FAO/WHO, 2004).

3.4. Intake and digestibility of feed nutrients

The ingredients of concentrate mixtures and chemical composition of Napier silage, VWP and concentrates are presented in Tables 4 and 5, respectively. The intake and apparent digestibility coefficient of feed nutrients are presented in Table 6. The initial and final LW of bulls of both dietary groups did not differ significantly (Table 6; $P > 0.05$). However, DM intake (DMI) in bulls of the C-mix group was higher than

Table 4
Feed ingredients of conventional and VWP concentrate mixtures (% fresh).

Ingredients	C–mix concentrate	VWP-mix concentrate
Rice polish	6	0
Maize Broken	30	12
Wheat bran	40	16
VWP	0	50
Soybean meal	20	18
Dicalcium phosphate (DCP)	2	2
Common salt	2	2
Total	100	100

C-mix, concentrate mixture with conventional ingredients; VWP-mix, concentrate mixture with VWP and conventional ingredients; VWP, vegetable wastes processed feed.

Table 5
Chemical composition of Napier silage, VWP and concentrate mixtures.

Parameters	Napier silage	VWP	C-mix	VWP-mix
DM (g kg^{-1}fresh)	182	900	916	917
OM (g kg^{-1}DM)	915	858	897	860
CP (g kg^{-1}DM)	77	127	164	161
NDF (g kg^{-1}DM)	650	450	311	366
ADF (g kg^{-1}DM)	450	340	178	297
TDN (% calculated)	–	63.8	–	–
GE (MJ kg^{-1}DM)	–	14.3	–	–

VWP, vegetable wastes processed feed; C-mix, concentrate mixture with conventional ingredients; VWP-mix, concentrate mixture with VWP and conventional ingredients; DM, dry matter; OM, organic matter; CP, crude protein; NDF; neutral detergent fiber; ADF, acid detergent fiber; TDN, total digestible nutrients; GE, gross energy.

Table 6
Intake and digestibility of feed nutrients by dietary groups of bulls.

Parameters	Napier silage + C-mix	Napier silage + VWP-mix	SEM	*P* –Value
Initial LW (kg)	66.22	67.17	1.72	NS
Final LW (kg)	78.35	73.58	3.00	NS
Total LW gain (kg)	12.13	6.42	2.65	NS
Average daily gain (gd^{-1})	357	189	77.87	NS
DMI (kg d^{-1})	2.46	1.93	0.09	< 0.01
FCE	6.56	10.21	3.31	NS
DMI from Napier silage (kg d^{-1})	1.06	0.87	0.07	< 0.05
DMI from concentrate (kg d^{-1})	1.40	1.06	0.04	< 0.01
DMI (% LW)	3.43	2.76	0.11	< 0.01
DMI from concentrate (% LW)	1.98	1.51	0.08	< 0.01
CP intake (g d^{-1})	311	240	0.078	< 0.01
DM digestibility coefficient	0.56	0.65	0.04	NS
CP digestibility coefficient	0.66	0.68	0.04	NS

C-mix, concentrate mixture with conventional ingredients; VWP-mix, concentrate mixture with VWP and conventional ingredients; VWP, vegetable wastes processed feed; SEM, standard error of mean; $P > 0.05$, not significant; LW, live weight; DMI, dry matter intake; FCE, feed conversion efficiency; CP, crude protein.

those of VWP-mix group. The daily DMI of C-mix diet (2.46 kg d^{-1}, 0.0343 LW) was reduced significantly ($P < 0.01$) on feeding the VWP-mix (1.93 kg d^{-1}, 0.0276 LW) containing VWP, and the extent of reduction may be explained by the reduced daily intake of Napier silage (1.06 vs 0.87 kg d^{-1}, respectively, $P < 0.01$) and of concentrate (1.40 vs 1.06 kg d^{-1}, respectively, $P < 0.05$). The difference in daily intake of total DM resulted in a significant reduction of daily CP intake (311 vs 240 g d^{-1}, respectively, $P < 0.01$). Animals on the treatment diet had a daily intake of 530 g VWP (0.50 of VWP-mix intake, Table 6), representing about 0.76% of average LW (VWP intake ÷ average LW × 100). The VWP, thus, constituted to about 275 g kg^{-1}DMof the diet (27.5% of dietary DM) of bulls of VWP-mix group (VWP intake ÷ total DM intake; Table 6). The VW is composed of a number of vegetables which are not conventionally fed to cattle. It may be stated that, the VWP is rich in nutrients and safe from the point of view of presence of some heavy metals (lead, chromium), pesticide residues and aflatoxins, but feeding of VWP at 275 g kg^{-1}DM of the diet may have resulted in reduced feed intake in bulls. Considering the chemical composition and in sacco digestibility of vegetable waste, the above dietary level of VWP was included. But, palatability of VWP containing different types of vegetable having a variable level of anti-nutritional compounds like tannins (Garg et al., 1992) may have resulted in reduced DM intake. It is, therefore, needed to carry out further study to determine a safe inclusion level that does not affect the dietary appetite and intake of bulls.

According to the Bangladesh Standard and Testing Institute (BSTI, 2008), the daily DM, TDN and CP requirements of a 70 kg native growing bull with an average daily gain up to750 g may be 1.79–2.61 kg, 0.75–1.52 kg, and 137–426 g, respectively. The daily intake of DM, TDN and CP of the experimental bulls ranged from 1.93 to 2.46 kg, 1.2 to 1.64 kg and 240–311 g, respectively. Thus, both the diets, having no significant ($P > 0.05$) differences in the digestibility coefficient of DM and CP, supplied the required amount of dietary energy and protein to bulls, and all of them gained LW during the trial period.

3.5. Blood biochemical parameters

The quality and quantity of diet may change the blood metabolites of cattle (Ndlovu et al., 2009). Moreover, the level of two enzymes: SGPT and SGOT in blood are used for diagnosing health status of the liver (Silanikove & Tiomkin, 1992), while blood creatinine is used to assess kidney function (Allen, 2012) in cattle. Blood metabolic profile (BS, BUN, LDL and HDL) and liver and kidney function tests (SGOT, SGPT and creatinine) of the bulls are presented in Table 7. The level of BS, total cholesterol, triglyceride, LDL and HDL cholesterol were not affected ($P > 0.05$) by feeding of VWP-mix. According to Radostitis, Gay, Blood, and Hinchcliff (2000) the level of BS in bull serum of the present study was within normal physiological range level for cattle, and it ranged from 2.5 to 4.17 mmol L^{-1}. This indicates that the animals had no dietary carbohydrate deficiency. The normal range of total cholesterol, triglyceride and LDL cholesterol of healthy cattle is 65–220, 0–14 and 0–100 mg dl^{-1}, respectively. In the present study, the levels of total cholesterol, triglyceride and LDL cholesterol were within normal physiological range, suggesting that feeding of VWP-mix at a level of 0.76% of LW or 270 g kg^{-1}DM of diet may not change lipid profiles of the animals.

However, the level of blood urea nitrogen (BUN) was significantly ($P < 0.05$) lower in the animal fed VWP-mix diet than that of the control animals fed C-mix diet. A lower BUN concentration may be the result of significantly ($P < 0.05$) lower CP intake by the former animals. The BUN is a measure of dietary protein adequacy as well as nitrogen utilization efficiency. Moreover, BUN gives important information about how well kidneys and liver function. The normal range of BUN in cattle is 6–27 mg dl^{-1} (Radostitis et al., 2000). The BUN concentrations in bulls of the dietary groups were within normal physiological level, suggesting that there was no protein deficiency of the animals, and the

Table 7
Blood metabolites in bulls fed various diets.

Blood metabolic profile	Napier silage + C- mix	Napier silage + VWP-mix	SEM	*P* -Value
BS (mmol L^{-1})	4.22	4.07	0.11	NS
BUN (mg dl^{-1})	23.67	19.5	1.40	< 0.05
Total cholesterol (mg dl^{-1})	81.33	69.00	7.44	NS
Triglyceride (mg dl^{-1})	26.60	23.67	4.11	NS
LDL (mg dl^{-1})	52.33	49.17	9.03	NS
HDL (mg dl^{-1})	22.33	20.17	2.50	NS
Liver and kidney function tests				
SGPT (U L^{-1})	36.33	28.50	3.61	NS
SGOT (U L^{-1})	73.50	54.40	9.09	NS
Creatinine (mg dl^{-1})	1.08	1.37	0.09	< 0.05

C-mix, concentrate mixture with conventional ingredients; VWP-mix, concentrate mixture with VWP and conventional ingredients; VWP, vegetable wastes processed feed; SEM, standard error of mean; $P > 0.05$, not significant; BS, blood sugar; BUN, blood urea nitrogen; LDL, low density lipoprotein; HDL, high density lipoprotein; SGPT, Serum Glutamic Pyruvic Transaminase; SGOT, Serum Glutamic Oxaloacetic Transaminase.

kidney and liver of the animals were working normally. Lower BUN in the VWP-mix animals could have beneficial effects on animals in this group since conversion of ammonia to urea by the liver is a highly energetic process (Turko & Reichenbecher, 2010) and energy could be utilized for anabolic processes in the animals.

The serum levels of SGOT and SGPT are widely used for diagnosing hepatic damage in domestic animals. The SGOT and SGPT of the dietary groups were not affected by the diets ($P > 0.05$), and were within the normal physiological level for healthy bulls as reported by Radostitis et al. (2000). This suggests that liver function was normal in bulls fed the VWP-mix. The normal range of SGPT and SGOT in cattle serum is 10–40 and 78–132 U L^{-1}, respectively. The creatinine concentration was found to be significantly higher ($P < 0.05$) in bulls fed VWP-mix diet. Creatinine is produced by metabolism of amino acids, released spontaneously into the bloodstream at a relatively constant rate, and is entirely excreted by the kidneys (Allen, 2012). Therefore, increased serum creatinine level is an indicator of impaired kidney function. However, the blood creatinine level of the bulls in both the dietary groups did not exceed normal physiological levels. The normal physiological range of creatinine in cattle reported to be 1–2 mg dl^{-1} (Radostitis et al., 2000).

4. Conclusions

Considering the chemical composition, in sacco DM degradability, and feed safety aspects (negligible levels of chromium, lead, total aflatoxin and some pesticide residues), it may be concluded that VW of both households and marketplace could be used as a feed ingredient for cattle. It may also be concluded that dietary inclusion of processed VW feed at the rate of 275 g kg^{-1}DM (27.5% of diet) or 0.76% of LW of bulls may result in reduced dietary intake ($P < 0.01$) simultaneously with increased serum creatinine level ($P < 0.05$) without affecting digestibility. Further research is required to determine the dietary level of processed VW feed in growing bulls to realize optimum production without affecting feed intake and productivity. Year round quantification of recyclable VW biomass as a feed, and development of a sustainable feed manufacturing technology from this may help increase market feed supply by minimizing food-feed competition for cultivable land, and may potentially reduce environmental pollution.

Conflicts of interest

We declare that there is no conflict of interest with any financial organization about the material discussed in this manuscript.

Ethical approval

The article reports on responses of growing bulls fed processed vegetable waste. This research work was approved by the 'Research Project Evaluation Committee' of Bangladesh Livestock Research Institute, Savar, Dhaka. During this trial period, all the guidelines followed were in accordance with the protocol of animal experimentation ethics committee (AEEC) of International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b).

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