Feeding of vegetable waste silage to lambs by replacing maize silage

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ABSTRACT
The study examined the vegetable waste (VW) silage as feedstuff for lambs. Therefore, mechanically shredded VW was ensiled solely (T0) or by adding molasses (95:5 ratio; T1), or molasses and either wheat bran (T2) or rice polish (T3) or rice straw (T4) at an 85:5:10 ratio in 5 replicates for 45 days for evaluation. Then, the maize silage diet of two of the three groups of lambs (S each) of 9.92 (±1.25) kg live weight (LW) was replaced with T4 silage at 50% and 100% on a fresh basis for 90 days and supplemented with a concentrated mixture at 1.5% of LWs. The significantly different pH (5.88, 5.21, 4.34, 4.33 and 4.23, respectively), lactic acid bacteria (not detected, 5.81, 6.51, 7.48 and 6.04 log10 cfu/g, respectively), and total volatile fatty acids (21.0, 29.2, 32.4, 36.0 and 32.0 mM/L, respectively) (P < .01) indicated that T2, T3 and T4 were of good quality silage. The dry matter intake and gain of lambs fed 100% T4 silage were significantly (P < .01) higher than others (2.30, 2.30 and 2.72% LW, respectively; 110, 128 and 141 g/d, respectively). It may be concluded that T4 silage may produce higher LW gain in lambs than maize silage.

1. Introduction
The environmental and socio-economic impact of food and vegetable waste (VW) biomass is a global concern. About one-third of the global food supply is wasted annually (almost 1.3–1.6 10^9 t), which may require approximately 1.5 10^9 ha of cultivable land for production (Fox and Fimeche 2013). This huge food and VW biomass may emit annually about 3.3 10^9 t CO_2 equivalent greenhouse gas from their dumping sites and cause global warming (Fox and Fimeche 2013). In Bangladesh, urban households produce about 3.29 10^6 t of food and VW, emitting about 2.19 10^6 t CO_2 equivalent greenhouse gas per year from their landfill sites (Enayetullah et al. 2006). Therefore, recycling and reusing VW, instead of dumping it into landfills, may help reduce its negative impacts on the environment.

Processing VW as feed for ruminants may increase market feed supply in a feed-deficient country like Bangladesh, where annual roughage and concentrate dry matter (DM) deficiency were about 44.5% and 79.6% of annual demand, respectively (Huque and Sarker 2014). Considering this, the nutritional values of VW as feedstuff of ruminants were examined in some previous studies. Das et al. (2018) reported that the nutritive value of mixed summer VW was similar to wheat bran or groundnut hay in terms of crude protein (CP, 14–17%), neutral detergent fibre (NDF, 37–41%) and total digestible nutrients (TDN, 63–67%). Some winter VW (cabbage, cauliflower, radish and carrot) was rich in CP (17–23%) and TDN (58–73%) (Das et al. 2019). Similarly, Angulo et al. (2012a) reported that mixed fruit and VW from marketplace sources might contain 9.1–11.6% CP, 32–43% NDF, 14.7–15.9 MJ/kg DM metabolizable energy (ME) with the rumen degradability of 82.9–89.8% at 24 h incubation in vitro. The suitability of VW as feedstuffs for ruminants was also reported previously. Higher conjugated linoleic acid and α-linolenic acid in milk were found when lactating cows were fed diets containing 18.0% processed fruit and VW (Angulo et al. 2012b). Processed VW was found free from pesticide residues, heavy metals (Pb and Cr) and total aflatoxins (Das et al. 2018). A feeding trial in growing bulls revealed no negative impacts on animal health, as indicated by normal kidney and liver functions when fed processed VW at 9.7% of dietary DM, or 0.30% of the live weight (LW) of growing bulls (Das et al. 2019). Lambs, which were fed on broccoli by-products (stem and leaves) (Brassica oleracea) and wheat straw mixed silage (69:31 ratio, DM basis) for 70 days at 20% of the diet, showed no adverse effect on health and productivity (Partovi et al. 2020). Feeding of fresh Chinese cabbage (B. oleracea) or cabbage (B. oleracea) or cauliflower leaves (Brassica campestris) by replacing 57–66% of para grass (Brachiaria multica) from the diet of goats showed lower DM intake than goats fed on a para grass diet. This might be because of their lower DM content (4–10%) than para grass (16%) (Nгу and Ledin 2005).

However, the process and preservation of VW as animal feedstuff is difficult due to its high moisture content and perishability. The moisture content of common VW in Bangladesh was reported as 83–96% (Das et al. 2019) and drying them for preservation may incur high costs and efforts. Instead of drying, ensiling VW with conventional dry roughage or concentrate (as absorbent) could be a potential cost-effective technique of preservation. For example, Özkul et al. (2011) reported producing a
good quality VW silage (87.8% moisture) by adding wheat straw and wheat bran at 29% and 9–20%, respectively, as absorbents. In Bangladesh, rice straw, wheat straw and rice polish are conventionally used year-round available feedstuff to feed ruminants (Khan et al. 2008; Huque and Sarker 2014; Uddin and Akter 2019), which could be added as absorbents in ensiling VW. In addition to the absorbent, applying molasses could also enhance the VW ensiling process, as it supplies readily fermentable sugars to lactic acid bacteria (LAB), which produce lactic acid in anaerobic fermentation, ensuring silage preservation (Colombatto et al. 2003; Mtengeti et al. 2013). Considering these, the present study investigates the effects of ensiling VW added with wheat bran, rice polish and rice straw along with molasses and the impact of feeding such silage on intake, digestibility and growth performances of lambs.

2. Materials and methods

2.1. Ensiling VW

Fresh VW (cabbage and cauliflower leaves at a 3:1 ratio, as found in the marketplace) from a local vegetable market (Ganda Bazar, Savar, Dhaka 1341) was collected during 18–20 October 2017. After collection, VW was scattered on a concrete floor, and non-VW, such as plastic rope, paper, and polyethylene bags, was removed manually. Then, any dirt and sand were removed from it by spraying sufficient tap water. After cleaning, VW was kept in a pile for about one hour to shed water, followed by shredding and dewatering by passing through a screw-press machine (Thresher model: YHSS-1 presser, Henan Yinhao Machinery Equipment Co. Ltd., China). The dewatering capacity of the machine was 15.6% (±3.4), depending on the level of screw-press control. Also, the machine broke the leaf stems, petioles and midribs into small pieces (2–3 cm) and mixed them thoroughly. This processed VW was ensiled solely (T0 control) or by mixing with molasses (95:5 ratio; T1), or molasses and wheat bran (85:5:10 ratio; T2), molasses and rice polish (85:5:10 ratio; T3) or molasses and chopped rice straw (85:5:10 ratio; T4) freshly in 35 kg plastic bags, was removed manually. Then, any dirt and sand were removed from it by spraying sufficient tap water. After cleaning, VW was kept in a pile for about one hour to shed water, followed by shredding and dewatering by passing through a screw-press machine (Thresher model: YHSS-1 presser, Henan Yinhao Machinery Equipment Co. Ltd., China). The dewatering capacity of the machine was 15.6% (±3.4), depending on the level of screw-press control. Also, the machine broke the leaf stems, petioles and midribs into small pieces (2–3 cm) and mixed them thoroughly. This processed VW was ensiled solely (T0 control) or by mixing with molasses (95:5 ratio; T1), or molasses and wheat bran (85:5:10 ratio; T2), molasses and rice polish (85:5:10 ratio; T3) or molasses and chopped rice straw (85:5:10 ratio; T4) freshly in 35 kg plastic drum silos (volume = 0.064 m³; the height and radius were 0.56 and 0.19 m, respectively) in 5 replicates. The molasses, wheat bran, rice polish and rice straw were purchased from a local market in a single lot and used for all silage replications of different groups. A polyethylene bag was placed into each drum before pouring silage materials. The silo was made anaerobic by pressing ensiled materials intermittently after each 30 cm filling. After filling, the polythene bag was tied with a cable tie, and the drum was covered with the lid. The drums were kept at room temperature (25 ± 5°C) for 45 days. Representative samples of fresh silage materials (about 500 g) from all treatments were sent to the laboratory for determining chemical compositions and other laboratory analyses. The chemical composition of silage materials before ensiling is presented in Table 1.

2.2. Fermentation and nutritive quality of silage

The fermentation characteristics and nutritive values of silage were studied by collecting representative fresh silage samples from different replicates. On the 45th day opening, the surface layer of decomposed silage was removed. Then, about 1 kg of silage from each layer of the top, middle, and bottom of the drum was collected and composited thoroughly for laboratory analysis.

For studying fermentation characteristics, about 20 g of each fresh silage sample was homogenized with 180 ml sterile double distilled water by a laboratory blender for 30 s, and silage extract was collected by filtering through four layers of cheesecloth according to Kim et al. (2016). The silage extract was used for microbial enumeration and considered the first dilution. The LAB, yeast and mould were enumerated using Lactobacillus MRS and PDA agar, respectively, as described by Amanullah et al. (2014) by examining diluted silage extracts at 10–5–10–7. The pH was measured from fresh silage extract with a pH meter (HachsensIONTM+; Hach, USA). The NH3-N and total volatile fatty acids (TVFA) (acetic acid, propionic acid, butyric acid and valeric acid) were determined according to Preston (1995) and Warner (1964), respectively.

On the same day, the chemical composition of the silage was analyzed by collecting a representative sample from each replicate (about 500 g). The DM content was determined by drying fresh silage (about 10 g samples) in an oven (NF 400, NUVE dry heat oven; NUVE, Turkey) at 105°C for 24 h. The remaining portion was dried at 60°C for 48 h, and ground in a Wiley mill (Thomas-Wiley Laboratory Mill, Thomas Scientific, USA), and passed through a 1-mm sieve and stored in properly labelled sample bottles until analyzed for chemical composition. Due to the higher availability of rice straw than other conventional absorbents (wheat bran and rice polish) at different seasons in Bangladesh (Huque and Sarker 2014), the feeding impact of T4 silage on lambs was studied once silage quality evaluation was completed. The T4 silage was produced in bulk by collecting VW during 14–20 December 2017 according to the same method and fed to lambs at 100-day ensiling.

2.3. Feeding of VW silage to lambs

Fifteen lambs of 4–6 months of age with an average initial LW of 9.9 (±1.25) kg were selected, dewormed with anthelmintics, and distributed randomly into three groups having five lambs in each. They were housed individually, and assigned to three dietary treatments for 90 days. In the control group, maize silage (Zea mays) was fed ad libitum as a basal roughage; it was produced by harvesting maize at 120 days of cultivation,

| Chemical composition, % DM | T0 | T1 | T2 | T3 | T4 |
|----------------------------|----|----|----|----|----|
| DM, % fresh                | 24.4| 26.8| 28.3| 28.7| 28.5|
| OM                        | 89.3| 89.2| 89.9| 89.1| 89.2|
| Ash                       | 10.7| 10.8| 10.1| 10.9| 10.8|
| CP                        | 18.6| 17.8| 15.6| 14.3| 13.7|
| NDF                      | 52.7| 50.6| 44.7| 50.1| 51.2|
| ADF                      | 24.8| 27.0| 27.0| 28.8| 31.6|
| EE                       | 1.1 | 1.2 | 2.1 | 3.7 | 1.5 |

Note: T0 = sole VW silage, T1 = VW silage with molasses at a 95:5 ratio, T2 or T3 = VW silage with molasses and either wheat bran or rice polish or rice straw at an 85:5:10 ratio, DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, EE = ether extract.
chopping it into 2–3 cm pieces, and ensiling in a pit for 25 days. In other groups, maize silage was replaced with T₄ silage at 50% or 100%, respectively, on a fresh basis. In the 50% T₄ silage group, an equal amount of fresh maize silage and T₄ silage were mixed manually and offered to the lambs. A concentrated mixture at 1.5% of LW of lambs was offered, irrespective of treatments. The concentrate mixture consisted of wheat bran, broken maize, soybean meal, khesari bran, dicalcium phosphate, common salt and protein concentrate at 30%, 30%, 20%, 16%, 1%, 1.5% and 1.5%, respectively. Fresh and clean drinking water was available all the time. The diets were supplied in equal halves at morning and evening meals (0800 and 1600 h, respectively). Lambs were weighed weekly before the morning meal, and the daily concentrate allowance was adjusted for the next week. Feed refusals were weighed and recorded daily in the morning. Ad libitum silage intake was maintained by supplying 20% extra compared to the intake of the previous day. Representative fresh silage and refusals (20%) were sampled weekly and stored at −20°C in a freezer (J86, GS36NW130G; Siemens, Germany) for analyzing chemical composition. Simultaneously, the DM content of fresh silage, concentrate mixture and refusals from individual sheep were determined weekly. At the end of the trial, all stored samples (silages, concentrate mixtures and refusals) were thawed at room temperature, pooled and mixed homogeneously to make a composite sample for each animal. Composite samples were then processed for analyzing chemical composition as described in the silage experiment section (fermentation and nutritive quality of silage). The chemical composition of feedstuffs is presented in Table 2.

### 2.4. Metabolism of nutrients in lambs

At the end of the feeding trial, all lambs were transferred for two weeks to individual metabolic crates with facilities to collect faeces and urine separately. The first week was for acclimatization with crates, and then the second week was for the collection of samples. The amount of feed supply, refusals, faeces voided and urine excreted every 24 h were measured in the morning (0700 h) daily. Urine was collected into a bucket set at the bottom of each crate containing 100 ml of diluted sulphuric acid (1:4) to prevent loss of volatile substances. Overnight fasted LW of the lambs was taken before and after the collection period, and the average was used to calculate nutrient metabolism. This research in lambs was aligned with animal research ethical guidelines of Bangladesh and approved by Bangladesh Livestock Research Institute.

During the collection period, the DM content of fresh silages (maize, mixed and T₄ silage) and refusals from individual sheep were determined daily. A representative sample of silages and refusals by each sheep was collected daily and stored at −20°C in the freezer (J86, GS36NW130G; Siemens, Germany). Fresh faeces were crushed manually and mixed thoroughly, and a representative sample (about 10% of faeces) was collected. A portion of the faeces sample was analyzed to determine DM content daily, while the other part was stored at −20°C. Urine samples of lambs were measured by a graduated cylinder, diluted to 1 L by adding ultra-pure distilled water, and an aliquot representing 10% of urine was stored in properly labelled plastic bottles at −20°C. Before analysis, all samples were thawed at room temperature, pooled, mixed thoroughly, and composited by individual lambs.

The ME and fasting heat (FH) production were determined according to Kearl (1982) and Chandramoni et al. (2000), respectively, and expressed in kilojoule (kJ) (1 Mcal = 4.184 MJ, 1 MJ = 1000 kJ). The following calculations were made:

\[ \text{ME} = \text{digestible organic matter (OM) intake (kg/d) \times 3.8, Mcal} \]
\[ \text{FH} = 54.1 \div W^{0.75}, \text{kcal/d, where } W^{0.75} \text{ is the metabolic LW of lamb} \]
\[ \text{Net energy (NE) = ME} \div \text{FH.} \]

### 2.5. Collection and analysis of blood samples

On the last day of the metabolic trial, blood samples were collected 2 h after the morning meal from the jugular vein into EDTA Tubes (K₂EDTA 6 ml; Cure Medical Tech Co., Ltd; Hillside, NJ07205, USA). Tubes were kept in an ice box and transported to the laboratory immediately after collection. Serum samples were separated using a Bench-Top Centrifuge (Type: NF 200; Nuve, Turkey) at 2500 rpm for 15 min and collected into Eppendorf tubes and stored at −20°C until analysis. Blood biochemica ls (blood sugar, urea nitrogen, total cholesterol, triglyceride, low-density lipoprotein, high-density lipoprotein and creatinine) and liver function enzymes (serum glutamic pyruvic transaminase) and serum glutamic oxalo-acetic transaminase were determined using a biochemical analyzer (Screen Master 3000; MedWOW, Cyprus) with commercial kits produced by RandoX (Randox Laboratories Limited, County Antrim, UK).

### 2.6. Chemical analysis of samples

The OM CP and ether extract (EE) contents were analyzed according to AOAC (2004). The NDF and acid detergent fibre (ADF) contents were determined according to Van-Soest et al. (1991), and results were expressed inclusive of ash. The TDN values were calculated according to Ball et al. (2001).

### 2.7. Statistical analysis

Data of the silage evaluation experiment were analyzed with the analysis of variance (ANOVA) of a completely randomized design (CRD) by the statistical package program, SPSS 11.5
In the case of the feeding trial, data were analyzed by the general linear model (GLM) procedure of CRD. The model used was as follows:

\[ Y_{ij} = \mu + T_i + e_{ij} \]

where \( Y_{ij} \) is the individual observation of a dependent variable; \( \mu \) is the overall mean; \( T_i \) is the fixed effect of different levels of VW silage (T4) in the diet of lambs, and \( e_{ij} \) is the residuals assumed to be normally distributed with mean zero. Significant differences between means were calculated using the standard error of means (SEM) at \( P < .05 \). A tendency of differences between means was declared at a \( P < .10 \).

3. Results

3.1. Fermentation and nutritive quality of silage

The quality characteristics (fermentation and nutritive) of different VW silages are presented in Table 3. The pH of T0, T1, and T4 silages was significantly lower (\( P < .01 \)) than that of T0 and T1 silages, respectively. The NH3-N content (g/kg DM or \% total N) was significantly higher (\( P < .01 \)) in T0, followed by T1, and either of T2, T3, or T4, respectively. The live viable count of LAB (Log10 cfu/g) was the highest in T3 (\( P < .05 \)) followed by T2 or T4 and T1, while it was not detected in T0 silage. A similar trend was found in TVFA content in silages (mM/L), where significantly higher TVFA was found in T3 (\( P < .01 \)) followed by T2 or T4 and T1 and T0 silage.

The DM and OM contents of T2, T3, and T4 were similar (\( P > .05 \)) but significantly higher (\( P < .01 \)) than those of T1 and T0 silage, respectively. The CP in T0 silage was highest (\( P < .01 \)) followed by T1, T2, T3, and T4 silage. Significantly higher (\( P < .01 \)) NDF was found in T4 silage compared to others, whereas ADF content was higher in T0 and T1 silage, followed by T4, T3, and T2 silage. The EE content in T2 silage was significantly higher than T3 and T0 or T1 or T4 silage (\( P < .01 \)). The estimated TDN (%) was highest (\( P < .01 \)) in T2, followed by T3, T0, T1 and T0 silage.

3.2. Intake and digestibility of nutrients

The intake and digestibility of nutrients of lambs fed different diets are presented in Table 4. The DM intake from maize silage (195 g/day) was increased significantly (\( P < .01 \)) when it was replaced with T4 silage at 50% (221 g/day) and 100% (298 g/day), respectively. Similarly, DM intake from the concentrate was higher (\( P < .01 \)) in either 50% or 100% T4 silage diets (144 g/day each) than the control. Concomitantly, total dietary DM intake (g/day) was higher (\( P < .01 \)) in 100% T4 silage-fed lambs (442 g/day) than 50% T4 silage (364 g/day) or the control (334 g/day). Similarly, the intake of OM, CP, NDF, and ADF was significantly higher (\( P < .01 \)) in lambs fed 100% T4 silage diet than 50% T4 silage- or the control-fed diet. There was no effect (\( P > .05 \)) of replacing maize silage with T4 silage on the digestibility coefficient of DM, OM, NDF, ADF, and hemicelluloses. However, digestibility coefficient of CP (\( P < .01 \)) in 50% and 100% T4 silage diets (0.44 and 0.51) was significantly higher (\( P < .01 \)) than that of maize silage diets (0.28).

3.3. Metabolism of nutrients

The metabolism of nutrients in lambs fed different diets is presented in Table 5. Dietary nitrogen intake and balance were increased significantly (\( P < .01 \)) by increasing the level of T4 silage in diets. Nevertheless, nitrogen excretion through faeces and urine was similar (\( P > .05 \)) among treatments. The ME intake in the 100% T4 silage diet was higher (\( P < .01 \)) than in other diets. The NE was also higher (\( P < .01 \)) when maize silage was replaced with 100% T4 silage (1864 kJ/day) than maize silage (878 kJ/day) and 50% T4 silage diet (1134 kJ/day).

3.4. Blood biochemical parameters

The blood biochemical parameters representing the health and nutrition status of lambs are presented in Table 6. Replacing maize silage with T4 silage as the basal diet of lambs did not affect serum sugar, creatinine, serum glutamic pyruvic

### Table 3. Fermentation and nutritive properties of the silage.

| Parameters                        | T0     | T1     | T2     | T3     | T4     | SEM   | \( P \)-values |
|-----------------------------------|--------|--------|--------|--------|--------|-------|---------------|
| pH                                | 5.88\( ^{A} \) | 5.21\( ^{B} \) | 4.34\( ^{C} \) | 4.33\( ^{C} \) | 4.23\( ^{C} \) | 0.19  | <.01          |
| NH3-N, g/kg DM                    | 2.56\( ^{A} \) | 1.99\( ^{B} \) | 1.04\( ^{C} \) | 1.08\( ^{C} \) | 1.00\( ^{C} \) | 0.07  | <.01          |
| NH3-N, % total nitrogen           | 9.09\( ^{A} \) | 7.26\( ^{B} \) | 4.31\( ^{D} \) | 4.86\( ^{C} \) | 4.71\( ^{C} \) | 0.33  | <.01          |
| LAB, Log10 cfu/g                  | nd     | 5.81\( ^{C} \) | 6.51\( ^{A} \) | 7.48\( ^{B} \) | 6.04\( ^{B} \) | 0.49  | <.01          |
| Yeast and mould                   | nd     | nd     | nd     | nd     | nd     | -     | -             |
| TVFA, mM/L                        | 21.00\( ^{C} \) | 29.20\( ^{B} \) | 32.40\( ^{B} \) | 36.00\( ^{A} \) | 32.00\( ^{B} \) | 2.93  | <.01          |
| Nutritive values (% DM)           |        |        |        |        |        |       |               |
| DM, (% fresh)                     | 12.3\( ^{C} \) | 16.9\( ^{B} \) | 25.1\( ^{A} \) | 24.8\( ^{A} \) | 24.2\( ^{A} \) | 0.67  | <.01          |
| OM                                | 79.1\( ^{C} \) | 82.1\( ^{B} \) | 87.6\( ^{A} \) | 87.4\( ^{A} \) | 87.4\( ^{A} \) | 0.56  | <.01          |
| Ash                               | 20.9\( ^{A} \) | 17.9\( ^{A} \) | 12.4\( ^{C} \) | 12.6\( ^{C} \) | 12.6\( ^{C} \) | 0.10  | <.01          |
| CP                                | 17.6\( ^{A} \) | 17.1\( ^{B} \) | 15.2\( ^{C} \) | 13.9\( ^{D} \) | 13.3\( ^{D} \) | 0.32  | <.01          |
| NDF                               | 45.4\( ^{A} \) | 45.1\( ^{B} \) | 40.6\( ^{C} \) | 45.8\( ^{B} \) | 46.8\( ^{B} \) | 0.11  | <.01          |
| ADF                               | 37.1\( ^{A} \) | 36.8\( ^{A} \) | 31.4\( ^{C} \) | 33.3\( ^{D} \) | 34.9\( ^{A} \) | 0.35  | <.01          |
| EE                                | 1.00\( ^{C} \) | 1.07\( ^{C} \) | 1.99\( ^{B} \) | 3.06\( ^{A} \) | 1.08\( ^{C} \) | 0.10  | <.01          |
| TDN                               | 61.8\( ^{B} \) | 62.1\( ^{D} \) | 65.9\( ^{B} \) | 64.2\( ^{A} \) | 63.4\( ^{C} \) | 0.42  | <.01          |

Note: VW = vegetable waste, T0 = sole VW silage, T1 = VW silage with molasses at a 95:5 ratio, T2, T3, or T4 = VW silage with molasses and either wheat bran or rice polish or rice straw at an 85:5:10 ratio, NH3-N = ammonia nitrogen, LAB = lactic acid bacteria, DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, EE = ether extract, TDN = total digestible nutrients, nd = not detected, SEM = standard error of the mean. \(^{A,B,C,D,E} = \) means within a raw with different superscripts differ significantly at \( P < .01 \).
transaminase, total cholesterol, triglyceride, high-density lipoprotein, and low-density lipoprotein levels (P < .05). However, urea nitrogen content was increased significantly when maize silage was replaced with T4 silage (P < .05). Also, serum glutamic pyruvic transaminase level was significantly (P < .05) reduced due to the complete replacement of maize silage with T4 silage.

### 3.5. LW gain of lambs

The effects of replacing maize silage with T4 silage on the LW gain of lambs are presented in Table 7. There was no difference (P > .05) in the initial LW of lambs in different treatments. In the end, the final LW tended (P = .070) to be higher in lambs when maize silage was replaced at 50% or 100% levels. Finally, the daily gain in lambs fed 100% T4 silage had significantly higher (P < .05) daily LW gain (141 g) than maize silage and 50% T4 silage-fed groups (110 and 128 g, respectively). The feed conversion ratios of lambs in different dietary groups were similar (P > .05).

### 4. Discussion

#### 4.1. Fermentation and nutritive quality of silage

The lower pH levels in molasses-added silages (T1 to T4 silage) than the control might be due to an additional water-soluble carbohydrates from molasses, which produced lactic acid by LAB (Colombatto et al. 2003; Mtengeti et al. 2013). The higher CP contents in fresh silage material before ensiling (T0 = 17.8%; Table 1) than other silage materials may result in a higher pH level in T0 silage. The good quality silage may have a pH of around 4.3 (Man and Wiktorsson 2002), achieved by silages added with molasses along with absorbents. The lower level of NH3-N in molasses-added WV silages than the control (T0) might be attributed to lower proteolysis, as molasses restricts proteolysis by reducing silage pH (Colombatto et al. 2003; Mtengeti et al. 2013). Proteolysis becomes restricted in silage at pH 4.3 or below (Man and Wiktorsson 2002), achieved by those three silages. The addition of wheat bran, rice polish or rice straw further reduced proteolysis in T3 and T4 silages, as it was mediated by reduced moisture content at the ensiling time (Table 1) compared to the control and T1 silage. Earlier reports suggest that low moisture content reduces proteolysis in silage (Ferris and Mayne 1994; Yahaya et al. 2001). Thus, it may be stated that lower DM level in T5 silage (12.3%, Table 3) may result from lower DM content of its fresh material (24.4%, Table 1) and greater proteolysis during the ensiling period. The higher LAB count in the later three silages (T2, T3, and T4) in this study was further linked with added molasses, which supplied water-soluble carbohydrates for LAB as nutrients. This result corroborates with the findings of Chen et al. (2014). The LAB concentrations

### Table 4. Intake and digestibility of nutrients in lambs.

| Parameters                        | Replacing maize silage with T4 silage | 0% | 50% | 100% | SEM  | p. |
|-----------------------------------|--------------------------------------|----|-----|------|------|----|
| Intake of nutrients               |                                      |    |     |      |      |    |
| DM intake from silage, g/d        |                                      | 195 | 221 | 298  | 12.51| <.01|
| DM intake from concentrate, g/d   |                                      | 139 | 144 | 144  | 0.08 | <.01|
| CP intake, g/d                    |                                      | 334 | 364 | 442  | 12.49| <.01|
| Total DM intake, % LW             |                                      | 2.30| 2.30| 2.74 | 0.16 | .002|
| OM intake, g/d                    |                                      | 291 | 320 | 407  | 11.10| <.01|
| CP intake, g/d                    |                                      | 42.71| 54.53| 69.21| 0.93 | <.01|
| NDF intake, g/d                   |                                      | 179 | 205 | 250  | 8.84 | <.01|
| ADF intake, g/d                   |                                      | 107 | 129 | 158  | 6.79 | <.01|
| Digestibility coefficient of nutrients |                                  |    |     |      |      |    |
| DM                                |                                      | 0.62| 0.60| 0.58 | 0.05 | .554|
| OM                                |                                      | 0.54| 0.57| 0.58 | 0.04 | .441|
| CP                                |                                      | 0.28| 0.44| 0.51 | 0.07 | <.01|
| NDF                               |                                      | 0.47| 0.49| 0.53 | 0.07 | .379|
| ADF                               |                                      | 0.50| 0.44| 0.43 | 0.07 | .384|
| Hemicelluloses                    |                                      | 0.44| 0.60| 0.71 | 0.17 | .080|

Note: T4 = WV silage with molasses and rice straw at an 85:5:10 ratio; DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, SEM = standard error of the mean.

### Table 5. Metabolism of nutrients in lambs.

| Parameters                        | Replacing maize silage with T4 silage | 0% | 50% | 100% | SEM  | p. |
|-----------------------------------|--------------------------------------|----|-----|------|------|----|
| Nitrogen metabolism               |                                      |    |     |      |      |    |
| Nitrogen intake, g/d              |                                      | 7.31| 9.39| 11.53| 0.22 | <.01|
| Nitrogen in faeces, g/d           |                                      | 0.22| 0.22| 0.23 | 0.03 | .564|
| Nitrogen in urine, g/d            |                                      | 0.28| 0.34| 0.44 | 0.09 | .062|
| Nitrogen balance, g/d             |                                      | 6.81| 8.83| 10.85| 0.19 | <.01|
| Energy metabolism                 |                                      |    |     |      |      |    |
| ME intake, kJ/d                   |                                      | 2837| 3245| 3358 | 318  | <.01|
| Heat loss, kJ/d                   |                                      | 1960| 2112| 2129 | 131  | .121|
| NE, kJ/d                          |                                      | 878 | 1134| 1862 | 336  | <.01|

Note: T4 = WV silage with molasses and rice straw at an 85:5:10 ratio; ME = metabolizable energy, SEM = standard error of the mean.

### Table 6. Blood biochemical properties of lambs.

| Parameters                        | Replacing maize silage with T4 silage | 0% | 50% | 100% | SEM  | p. |
|-----------------------------------|--------------------------------------|----|-----|------|------|----|
| Sugar, mg/L                       |                                      | 102.20| 99.76| 94.97| 6.11 | .204|
| Urea nitrogen, mg/dL              |                                      | 55.34| 69.20| 72.54| 9.79 | .038|
| Creatinine, mg/dL                 |                                      | 0.66 | 0.74 | 0.53 | 0.22 | .350|
| Serum glutamic pyruvic transaminase, U/L |                                | 36.94| 38.06| 37.71| 3.15 | .849|
| Serum glutamic oxalo-acetic transaminase, U/L |                            | 82.80| 86.80| 47.69| 19.69 | .046|

Total cholesterol, mg/dL           |                                      | 48.20| 52.00| 91.94| 7.39 | .658|
High-density lipoprotein, mg/dL    |                                      | 14.60| 16.00| 13.97| 2.63 | .480|
Low-density lipoprotein, mg/dL     |                                      | 29.60| 31.00| 33.90| 6.28 | .560|
Triglyceride, mg/dL                |                                      | 18.80| 22.40| 17.73| 4.98 | .332|

Note: T4 = WV silage with molasses and rice straw at an 85:5:10 ratio; SEM = standard error of the mean.

### Table 7. LW gain of lambs.

| Parameters                        | Replacing maize silage with T4 silage | 0% | 50% | 100% | SEM  | p. |
|-----------------------------------|--------------------------------------|----|-----|------|------|----|
| Initial LW, kg                    |                                      | 9.79 | 10.06| 9.90 | 1.34 | .951|
| Final LW, kg                      |                                      | 19.72| 21.57| 22.59| 1.78 | .070|
| Gain, g/d                         |                                      | 110| 128 | 141 | 13.26 | .011|
| Feed conversion ratio             |                                      | 3.08| 2.86| 3.16 | 0.08 | .366|

Note: T4 = WV silage with molasses and rice straw at an 85:5:10 ratio; SEM = standard error of the mean.
in these silages (6.04–7.48 log10 cfu/g) were higher than the minimum threshold level required for successful ensiling (10^5 cfu/g; Cai et al. 2003). Özkul et al. (2011) reported producing good quality VW silage containing cauliflower, cabbage and artichoke leaves at 33%, 22% and 17%, respectively when ensiled with wheat straw (4–20%) and wheat bran (9–15%) as absorbent.

The higher DM and OM, but lower CP content in T_2, T_3 and T_4 silages than the control and T_1 silages might have resulted from cumulative effects of the chemical composition of fresh silage mixtures (Table 1) and their anaerobic fermentation characteristics (Table 3). The level of DM degradation in silage (0–28%; Goeser et al. 2015) by bacterial fermentation is proportional to the moisture content of ensiled materials (Wayne et al. 1998). In the present study, the inclusion of wheat bran, rice polish or rice straw decreased moisture and CP contents in 1998). In the present study, the inclusion of wheat bran, rice polish or rice straw decreased moisture and CP contents in fresh mixtures of T_2, T_3 and T_4 silages compared to the control and T_1 (Table 1), which might have resulted in higher DM and lower CP contents in them (Table 3). Moreover, molasses-added silages (T_1–T_4) contained higher DM levels (16.9–25.1%; Table 3) compared to control (12.3%; Table 3), as molasses might stimulate more excellent anaerobic fermentation of them by supplying its soluble sugars to LAB (Alli et al. 1984), retarding DM degradation. Chen et al. (2014) also reported higher DM levels in corn silage when supplemented with molasses at a 3% level than in control. The lower DM content in T_0 silage (12.3%, Table 3) might be consisted in greater DM degradation during ensiling due to the lower DM content of its fresh materials (24.4%, Table 1), compared to that of others.

Similarly, NDF ADF and EE levels of fresh materials (Table 1) might be responsible for their silage levels. Bacterial degradation of organic materials might be responsible for variation in NDF and ADF in silages. The chemical composition of T_4 silage used in the silage evaluation study (Table 3) and that in the feeding trial to lambs (Table 2) was different. The difference might be due to the difference in the time of collection and ensiling of VW. Such variation in the chemical composition of VW in different seasons of a year was reported previously (Das et al. 2019).

4.2. Intake, digestibility and metabolism of nutrients

The higher intake of silage DM in 50% and 100% T_4 silage might be due to its molasses content. Adding molasses increases the palatability of roughages in ruminant’s diet (Kamalak et al. 2002). Concomitantly, the increased intake of OM, CP, NDF and ADF in T_4 silage resulted from increased DM intake in those groups (Table 4). The digestibility of CP in maize silage was found lower in this study. This lower CP digestibility in maize silages may be attributed to its heat damage, as Cressman et al. (1979) reported 30% CP digestibility of heat-damaged silage by 30-day ensiling at high temperature (70° C). Unwanted infiltration of air to maize silage due to insufficient compaction or management problem might be responsible for this, as greater oxidation of sugars produces more temperature inside the silo. The differences in nitrogen intake and balance due to replacing maize silage with T_4 silage were due to differences in intake and digestibility of CP (Table 4).

Similarly, variation in energy intake and metabolism was also derived from differences in intake of DM and other nutrients in different treatments (Table 4).

4.3. Blood biochemical parameters

The serum sugar concentrations, reflecting the energy status of lambs, did not vary among treatments, as the lambs of all groups were in positive energy balance (Table 4). Increased urea nitrogen level with the increasing T_4 silage was associated with increased nitrogen intake and balance in lambs under those groups (Table 5). The level of serum glutamic oxalo-acetic transaminase in maize and 50% T_4 silage-fed lambs was within the normal range of sheep (50–280 U/L; Radostitis et al. 2000), but it was slightly low at 100% T_4 silage-fed lambs. Lower serum glutamic oxalo-acetic transaminase is not a concern as liver function impairment is associated with its higher levels. All the blood biochemical properties, including metabolic profile (sugar and urea nitrogen), kidney and liver health profile (creatinine, serum glutamic pyruvic transaminase and serum glutamic oxalo-acetic transaminase) and lipid profile (total cholesterol, high-density lipoprotein, low-density lipoprotein and triglyceride) together, indicated the experimental lambs were in good health condition being fed on T_4 silage (Radostitis et al. 2000).

4.4. LW gain

The increased daily gain in lambs with the increased T_4 silage was attributed to the higher intake of nutrients (DM, OM, and CP; Table 4) and higher nitrogen balance compared to the control (Table 5). This relationship is further explained in Figure 1, which indicated a strong and significantly linear relationship between daily gain and ME (n=14, r=0.716; P<.0005), and nitrogen balance (n=13, r=0.555, P<.01) of experimental lambs irrespective of diets. From the relationship, it seems that the daily maintenance requirement of nitrogen in

![Figure 1. Relationship between daily LW gain (g/d) and ME (kJ/d) or nitrogen balance (g/d) in lambs. The solid line and closed circles represent ME, while the dotted line and open circles represent nitrogen.](image)
lambs was (7.159 g/day) within the range reported by Oliveira et al. (2017) (6.4–9.6 g/day). The ME for maintenance (2555 kJ) was lower than the values for tropical hair sheep in the same report (3005 kJ/day). A calorimetric study could attribute energy efficiency more accurately.

5. Conclusions
The results of the study indicate that VW of cabbage and cauliflower leaves may be preserved as good quality silage by adding molasses and either wheat bran, rice polish, or rice straw at 85:5:10 ratios, as indicated by lower pH and NH₃-N with higher LAB. Feeding of rice straw-based such silage to lambs by replacing maize silage may result in higher gain without affecting production performance and health.

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