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Feed potential of vegetable and citrus waste-based silage: ensiling quality, acceptability and effects on blood parameters of West African Dwarf sheep

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Abstract

Wastes generated from the production, processing and marketing of fruits and vegetables are potential environmental pollutants. However, these wastes can be converted into silage for ruminants. This study was aimed at evaluating the quality of silage made from vegetable and citrus wastes, their acceptability and the blood parameters of West African Dwarf (WAD) female sheep. A cafeteria feeding pattern was used to assess the acceptability of the silages by sheep. Sixteen female sheep with an average age of 16 ± 2 months were assigned to four diets of vegetable and citrus waste-based silages in a completely randomised design to evaluate blood parameters. The dietary treatments comprised: T_1 (40% vegetable waste, 20% citrus waste, 20% cassava peel, 10% wheat bran & 10% Gliricidia sepium leaf), T_2 (20% vegetable waste, 40% citrus waste, 20% cassava peel, 10% wheat bran & 10% Gliricidia sepium leaf), T_3 (40% vegetable waste, 20% citrus waste, 10% cassava peel, 20% wheat bran & 10% Gliricidia sepium leaf), T_4 (20% vegetable waste, 40% citrus waste, 10% cassava peel, 20% wheat bran & 10% Gliricidia sepium leaf). Results showed that the silage pH ranges from 3.82 to 4.07. All silages were acceptable, except for T_4, which had a coefficient of preference less than Unity (0.77). Dry matter intake and preference for silage were higher in T_1 (7.84kg and 29.05%) and lower in T_4 (5.25kg and 19.45%). The packed cell volume, red blood and white blood cells of the sheep were not different ($P>0.05$). The haemoglobin levels were comparable, though higher in T_1 (9.35g/dL) and lower in T_4 (7.10g/dL). Serum total protein of T_1 and T_3 ($P<0.05$) were higher than T_2 and T_4. Serum cholesterol was comparable ($P>0.05$), but T_2 was lower than T_3 ($P<0.05$). In conclusion, silages made from vegetable and citrus waste were acceptable and had no negative effect on health status of the sheep

Keywords: Horticultural waste, Silage, Ruminants, Preference, Blood assay

Potentiel fourrager de l'ensilage à base de déchets de légumes et d'agrumes : qualité de l'ensilage, acceptabilité et effets sur les paramètres sanguins du mouton Djallonké

Résumé

Les déchets générés par la production, la transformation et la commercialisation des fruits et légumes constituent des polluants environnementaux potentiels. Cependant, ces déchets peuvent être convertis en ensilage pour les ruminants. Cette étude visait à évaluer la qualité de l'ensilage fabriqué à partir de déchets de légumes et d'agrumes, son acceptabilité et ses effets sur les paramètres sanguins de brebis Djallonké (WAD). Un dispositif d'alimentation de type "cafétéria" a été utilisé pour évaluer l'acceptabilité des ensilages par les moutons. Seize brebis d'un âge moyen de 16 ± 2 mois ont été réparties selon un dispositif complètement randomisé entre quatre régimes à base d'ensilages de déchets de légumes et d'agrumes pour évaluer les paramètres sanguins. Les traitements alimentaires comprenaient : T_1 (40% de déchets de légumes, 20% de déchets d'agrumes, 20% d'épluchures de manioc, 10% de son de blé et 10% de feuilles de Gliricidia sepium), T_2 (20% de déchets de légumes, 40% de déchets d'agrumes, 20% d'épluchures de manioc, 10% de son de blé et 10% de feuilles de Gliricidia sepium), T_3 (40% de déchets de légumes, 20% de déchets d'agrumes, 10% d'épluchures de manioc, 20% de son de blé et 10% de feuilles de Gliricidia sepium), T_4 (20% de déchets de légumes, 40% de déchets d'agrumes, 10% d'épluchures de manioc, 20% de son de blé et 10% de feuilles de Gliricidia sepium). Les résultats ont montré que le pH de l'ensilage variait de 3,82 à 4,07. Tous les ensilages étaient acceptables, à l'exception du T_4, qui présentait un coefficient de *préférence inférieur à l'unité (0,77). L'ingestion de matière sèche et la préférence pour l'ensilage étaient plus élevées pour T_1 (7,84 kg et 29,05 %) et plus faibles pour T_4 (5,25 kg et 19,45 %). L'hématocrite, le nombre de globules rouges et de globules blancs des moutons n'étaient pas différents (P>0,05). Les taux d'hémoglobine étaient comparables, bien que plus élevés pour T1 (9,35 g/dL) et plus faibles pour T_4 (7,10 g/dL). La protéine sérique totale des groupes T_1 et T_3 (P<0,05) était plus élevée que celle des groupes T_2 et T_4. Le cholestérol sérique était comparable (P>0,05), mais le T_2 était inférieur au T_3 (P<0,05). En conclusion, les ensilages à base de déchets de légumes et d'agrumes étaient acceptables et n'ont eu aucun effet négatif sur l'état de santé des moutons.*

Mots-clés : Déchets horticoles, Ensilage, Ruminants, Préférence, Dosage sanguin

Introduction

Fruits and vegetables are largely grown in Nigeria for human consumption (Okaiyeto *et al.,* 2021). However, some fruits and vegetables that are not suitable for human consumption rot and are wasted (Ibeawuchi *et al.,* 2015). Horticultural crops contribute to waste generation on farms, at markets, processing sites and in households. These wastes are large and contribute to environmental pollution (Akande and Olorunnisola, 2018), and also serve as a breeding ground for some detrimental organisms, such as fruit flies from dropped citrus fruit in the orchard (Umeh *et al.,* 2004), if the fallen fruits are not picked. According to FAO (2011) reports, 45% of 60 million tons of cabbage produced globally is lost on the field, while Carvalho *et al.,* (2013) reported that about 16% of cabbage is lost at the market level of commercial processing. Dharmathilake *et al.,* (2020) also reported a 43% incidence of postharvest losses of cabbage, which was mainly from the trimming of outer leaves and 30% postharvest losses of carrots, mainly from the rots and mechanical damages.

In most markets across Nigeria's ecological zones, fruit and vegetable wastes are readily available and rarely influenced by season (NIHORT, 2022). Marketers sort out the good fruits and vegetables that meet the market grades and discard the rest as waste. Post-harvest losses of fruits and vegetables, from production to consumption, may be as high as 50% (Ibeawuchi *et al.,* 2015), indicating that field and market horticultural wastes such as citrus fruits, cabbage, and carrots are available in appreciable quantities. These wastes could be used in fresh, dried or ensiled forms in animal feeding (Church 1991). Vegetable and fruit wastes are nutrient-dense feed resources (Angulo *et al.,* 2012), which improve the health status and productivity of ruminants (Das *et al.,* 2022; Partovi *et al.,* 2020). Meanwhile, a judicious use of horticultural wastes, if ensiled with crop residues, cereal by-products and leaves of tree legumes, could improve the nutrition of livestock and boost productivity. Ensiling horticultural waste with their characteristic moisture will require addition of other agricultural waste as absorbent. Ensiling provides the opportunity to preserve feed resources for optimal livestock production. The ensiling quality of citrus pulp, vegetable and cabbage wastes for sheep are well documented (Das *et al.,* 2022; Papi *et al.,* 2022; Adegun and Ososanya 2023). According to Kenneth-Obosi *et al.,* (2020), quality livestock feed in the form of silage for ruminants can be produced from fruits and vegetable wastes. Meanwhile, preferences for feed by animals originated from the relationship between the taste of feed and post-ingestive gastrointestinal feedback (Provenza, 1995). A well-made silage is expected to have a fruity smell and should be palatable due to the anaerobic activities of microbes during fermentation.

The assessment of blood provides insight into health status and the detection of stress, which can be influenced by nutrition, genetics, animal breed, or environmental factors (Arfuso *et al.,* 2016; Atte and Opoola 2022; Kareem-Ibrahim *et al.,* 2023). Serum biochemical and haematological indices are critical for diagnosis, prognosis and treatment of livestock diseases (Onasanya *et al.,* 2015). In light of the above, the search for non-conventional silage for sustainable ruminant production will necessitate an investigation into the health status of the animals. This study was designed to assess the quality of silage made from vegetable and citrus waste, its acceptability, and the effect on haematological and serum biochemical indices of West African dwarf sheep.

Materials and methods

Experimental site

The study was carried out at the ruminant unit of the National Horticultural Research Institute (NIHORT), Ibadan, Nigeria. The site is located at the following latitude and longitude coordinates: 7.376736 and 3.939786, respectively.

Collection of feed materials and preparation of silage

Citrus waste was gathered from the wholesome dropped fruits in the Citrus orchards of the National Horticultural Research Institute (NIHORT), Ibadan. Cabbage and carrot wastes were collected from an exotic vegetable market in Ibadan. *Gliricidia sepium* was harvested within NIHORT, while cassava peel and wheat bran were purchased from an animal feed vendor in an open market.

The ensiling materials (citrus waste, vegetable (cabbage and carrot; 1:1) waste, dried cassava peel, wheat bran and *Gliricidia sepium* leaves) were weighed according to the proportions highlighted in Table 1 to form four dietary treatments. T1: citrus waste (24Kg), vegetable (cabbage and carrot; 1:1) waste (48Kg), dried cassava peel (24Kg), wheat bran (12Kg) and *Gliricidia sepium* leaves (12Kg); T2: citrus waste (48Kg), vegetable (cabbage and carrot; 1:1) waste (24Kg), dried cassava peel (24Kg), wheat bran (12Kg) and *Gliricidia sepium* leaves (12Kg); T3: citrus waste (24Kg), vegetable (cabbage and carrot; 1:1) waste (48Kg), dried cassava peel (12Kg), wheat bran (24Kg) and *Gliricidia sepium* leaves (12Kg); T4: citrus waste (48Kg), vegetable (cabbage and carrot; 1:1) waste (24Kg), dried cassava peel (12Kg), wheat bran (24Kg) and *Gliricidia sepium* leaves (12Kg), Each treatment was thoroughly mixed and packed into 120 L capacity plastic drums, lined with polyethene, and replicated thrice. The containers were filled in layers with ensiling materials, compressed, covered with nylon and tightened on completion to make them airtight. A sandbag weighing 50kg was placed on each plastic drum. The compressed feed materials were left to ferment anaerobically for 21 days. After 21 days of fermentation, a representative sample of each silage treatment was collected at different depths for analysis.

Table 1: Percentage composition (%) of vegetable and citrus waste-based silage

	Silage Treatments			
Materials ensiled	T_1	T_2	T_3	T_4
Citrus waste (whole fruit)	20	40	20	40
Vegetable waste (cabbage and carrot; 1:1)	40	20	40	20
Dried Cassava peel	20	20	10	10
Wheat bran	10	10	20	20
Gliricidia sepium leaf	10	10	10	10

Assessment of the physical characteristics of silages

The physical qualities of silage, such as smell, temperature, and texture, were evaluated as described by Ososanya and Olorunnisomo (2015) immediately after the silage was opened. A laboratory thermometer was inserted and kept inside the ensiled material for 5 min to determine the temperature. An equal quantity of silage and distilled water (10g: 10mL) was measured into a beaker for the determination of silage pH. The mixtures were stirred with a glass rod and allowed to stand for 30 min. The electrode of a digital pH meter (Eutech Instruments pH510) was immersed in the silage suspension to record its pH. The silage was oven-dried at 60°C for the determination of dry matter content.

Acceptability of silage trial

West African Dwarf female sheep (n = 8; body weight range = 11–13kg; average age = 12±2 months) were served each of the four silage treatments (350g each, replicated 3 times) in a cafeteria manner, as described (Larbi *et al.*, 1993), to allow free-choice intake. The sheep had access to the silages from 10.00hr to 15.00hr daily for seven days, excluding the first seven days of the adjustment period to the newly introduced silages. The silages were served in plastic feeding troughs, placed in strategic locations within the pen. The positioning of the silage in each trough was altered daily to prevent the animals from sticking permanently to a feed trough. Daily consumption was measured by the deduction of remnants from the quantity of feed served. The silage most preferred was assessed using a Coefficient of Preference (CoP), which considers the ratio between the intakes of the individual silages, divided by the average intake of the silage (Babayemi *et al.*, 2006). The CoP with a value above unity (1) was adjudged acceptable. Percentage preference was calculated from the ratio of the intake of individual silage divided by the total intake of all the silage, multiplied by 100.

Feeding of experimental diets

After the acceptability study, the WAD sheep (sex = female, n = 16, rep = 4, average weight = 13-16kg; average age = 16 ± 2 months) were randomly assigned to four diets, with four animals per treatment, in a Completely Randomised Design. Before the commencement of the animal experiment, pens were cleaned and disinfected. Animals were given prophylactic treatment: ivermectin injection (1mL/50kg body weight) was used against internal and external parasites, while albendazole was used against endoparasites, and a pour-on treatment was used against ectoparasites. Additionally, Oxytetracycline (a broad-spectrum antibiotic) at 1 mL per 10 kg body weight and a multivitamin injection were also administered to reduce stress. Silage and guinea grass were offered at 3.5% and 1.5% of their body weights in the morning (8.00hr) and evening (16.00hr), respectively. The silage composition was as stated in Table 1. The animals had free access to clean drinking water, experimental feed, Guinea grass and a mineral salt lick for 21 days before blood sample collection.

Collection and analysis of blood samples

Three animals were randomly selected per treatment for the collection of blood samples at day 21st of exposing the animals to the experimental feed. The animals were bled in the morning before feeding, for the collection of blood samples (5mL) via the jugular venipuncture. Blood samples (2.5 mL), immediately after collection, were transferred into labelled sterile bottles containing Ethylene Diamine-Tetra-Acetic acid (EDTA) for haematological analysis. The remaining blood sample (2.5 mL), intended for serum analysis was transferred into sample bottles free of heparin. The packed cell volume, haemoglobin, red blood cell, white blood cell, lymphocytes, neutrophils, monocytes, and eosinophils were measured as described by Jain (1986). Serum biochemicals (total protein, albumin, creatinine, cholesterol, and serum urea Nitrogen) were determined using standard procedures described by Dacie and Lewis (2001).

Proximate and statistical analyses

The dry matter, crude protein, ash and ether extract contents of the diets were analysed according to the procedures of AOAC (1995). The data collected were subjected to analysis of variance (ANOVA). Means were separated using Duncan Multiple Range Tests, and significant differences were declared at $P<0.05$.

Results and discussion

Physical characteristics of vegetable and citrus waste-based silage and its acceptability by West African Dwarf sheep

The physical characteristics and pH of the silages are presented in Table 2. All the silages had a pleasant, fruity, and acceptable smell, indicating high-quality silage (Kenneth-Obosi *et al.*, 2017). However, the smell/aroma of T_3 was adjudged more pleasant than the others. The original texture and structure of the pre-ensiled materials were maintained in silage treatments. The pH range (3.82-4.07) of the silages is within the acceptable pH value of 3.8-4.2, considered ideal for silage in the tropics (Maciel *et al.*, 2008) but slightly higher than the pH of 3.42-3.94 documented for vegetable waste silages (Astuti *et al.*, 2013). The water-soluble carbohydrate potential of cassava peel, wheat offal, carrots, and citrus fruits could explain the low pH, likely due to lactic acid production by lactic acid bacteria. Increased lactic acid production could result in a rapid drop in pH and a well-fermented silage (Bureenok *et al.*, 2005). Higher ensiling temperatures (> 30 °C) resulted in heat-damaged proteins and caramelisation of silages (Muck *et al* 2003; Adesogan 2010), due to excessive heat generated by heterofermentative lactic acid bacteria. In this study, silage temperatures ranged from 26°C to 27°C, and were slightly lower than values (27.00-29ºC) reported by Astuti *et al.,* (2013) for vegetable waste silages. The lower temperature (28.5°C) obtained may have contributed to the quality of silage and retention of the original colour of the pre-ensiled materials.

Table 2: Physical characteristics and acceptability of vegetable and citrus waste-based silage by West African Dwarf sheep

	Silage treatments			
Parameter	T_1	T_2	T_3	T_4
Smell	Pleasant fruity	Pleasant fruity	Highly Pleasant fruity	Pleasant fruity
Texture	Firm	Firm	Firm	Firm
Temperature	27°C	26°C	27°C	26°C
pH	4.01	3.82	4.06	4.07
% Dry matter	39.21	39.21	42.44	31.96
Acceptability of silage				
DM Intake (kg)	7.84	6.93	6.96	5.25
Preference (%)	29.05	25.68	25.79	19.45
Coefficient of Preference (CoP)	1.16	1.02	1.03	0.77

Dry matter intake, preference and coefficient of preference were relatively higher for T_1 than for other silage treatments (Table 2). Silages with 40% vegetable waste (T_1 and T_3) were more acceptable to the sheep than those with 40% citrus waste (T_2 and T_4). These effects may be attributed to the carrot, one of the components of the vegetable waste, which enhances appetite and increases silage consumption. This agrees with the observation of Laflamme (1992) in cattle fed a mixture of carrot/grass silage. The least preference for T_4 does not imply that the sheep outright rejected it. According to Oluremi *et al.* (2007) and Batool *et al.* (2020), citrus fruit peel is reportedly high in phytonutrients, at high levels of inclusion in the diet, it may have a negative impact on feed consumption. Therefore, the astringent sensation of citrus peel in the mouth, due to the higher percentage of citrus waste in the diet (T_4), probably reduced the palatability and intake of the silage by the sheep.

Table 3: Proximate composition of vegetable and citrus waste-based silage

	Silage Treatments				
Nutrient (%)	T_1	T_2	T_3	T_4	SEM
Dry Matter (DM)	49.49	54.72	51.01	49.75	2.61
Crude Protein (CP)	7.50^a	6.80^b	6.80^b	6.59^b	0.05
Ether Extract (EE)	0.06^b	0.09^a	0.08^{ab}	0.06^b	0.00
Crude Fibre (CF)	36.87^b	34.13^c	45.47^a	36.00^b	0.22
Ash	8.00	7.33	7.00	7.33	1.05
Nitrogen Free Extract (NFE)	47.57^{ab}	51.65^a	40.65^b	50.01^a	1.11

^{abcd} = Means in the same rows with different superscripts are different (P<0.05)
SEM Standard Error of Mean

Table Figure 3 shows the proximate composition and fibre fractions of the silage. There was no significant difference in the dry matter and ash contents of the silages. The crude protein of T_1 was higher (P<0.05) than for T_2, T_3 and T_4. The crude fibre content varied (P<0.05) from 34.13 to 45.47%. Nitrogen-free extracts (T_2 and T_4) containing 40% citrus waste were higher than those with 40% vegetable waste (T_1 and T_3). However, the NFE of T_1 (vegetable-based silage) with 20% cassava peel inclusion was comparable to that of citrus-based silages (T_2 and T_4). The ether extract values (0.06-0.09%) of silages were lower than the 0.30 to 1.17% EE reported by Astuti *et al.*, (2013) for vegetable waste silages. A lower ether extract content in the silage could be an indication of good-quality silage, according to Sapienza and Bolsen (2003), who reported that silages with an ether extract content above 2% are of poor quality. However, supplementation of the silages with dietary fat sources of not greater than 6% EE is suggested to improve intake and ruminal fermentation. The lower crude protein levels (<7% CP minimum) in the silages, except for T1, suggest the need for supplementation with protein sources to support optimal ruminal function and microbial protein synthesis. A higher level of nitrogen-free extracts revealed relatively more soluble carbohydrates in the citrus-based silage. This implies that citrus waste is rich in fermentable carbohydrates, which are potential energy sources, likewise carrots, which are rich in total digestible nutrients (Bakshi *et al.,* 2016). Therefore, the complementary effect of citrus and vegetable (carrot) wastes revealed the nutrient potential of the silage. According to Oloche *et al.* (2013), feed resources with sufficient soluble carbohydrates can be converted to the energy needed by animals for metabolic activities. Nonetheless, the crude fibre content of the silages was adequate to support healthy rumen function.

Haematological and Serum biochemical parameters of sheep fed vegetable and citrus waste-based silage

The haematological parameters of the WAD sheep fed vegetable and citrus waste-based silage are shown in Table 4. The Packed Cell Volume (PCV), Red Blood Cell (RBC) count, and White Blood Cell (WBC) count values ranged from 23.00-29.00%, 3.21-4.29 ($\times 10^6/\mu L$) and 3.78-5.28 ($\times 10^6/\mu L$), respectively. These parameters (PCV, RBC and WBC) were not different ($P>0.05$) across the treatments. Similarly, the white blood cell differential counts, except for eosinophils, were not different ($P>0.05$). The haemoglobin (Hb) of sheep on T_1 was significantly different ($P<0.05$) from T_4, and was comparable with sheep on T_2 and T_3. Meanwhile, the RBC values were below the normal range (9-15 $\times 10^6/\mu L$) for a healthy sheep. The white blood cell differential counts, except eosinophils, were also not different ($P>0.05$). The PCV and Hb across the treatments fell within the ranges of 26-36% and 8.07-11.70 g/dL, respectively, reported by Pampori (2003) for healthy sheep. However, the lower PCV, Hb, and RBC values obtained across treatments in this study were at the critical limits when compared with the normal ranges reported by Reece (2009) and Latimer *et al.* (2011). This is an indication of an anemic condition, likely caused by iron deficiency, reduced erythropoiesis, poor utilisation of iron for haemoglobin formation (Olafadehan 2011), and reduced oxygen-carrying capacity. The WBC is an indicator of immunological response to foreign bodies. The WBC count of the sheep was within the normal range (4-12 $\times 10^6/\mu L$), as reported (Reece 2009) for clinically healthy sheep, except for T_4. Similarly, the white blood cell differentials (lymphocytes, neutrophils, monocytes and eosinophils) were within the normal ranges reported for healthy WAD sheep (Kareem-Ibrahim *et al.,* 2023). Generally, non-significance and lower WBC counts observed across treatments (particularly T4) also indicated a reduced ability to fight infections associated with foreign bodies in the circulatory system. However, within the normal range of white blood cell differential, the results suggest an active immune response to infections or inflammation.

Table 4: Haematological parameters of sheep fed vegetable and citrus waste-based silage

Silage Treatments

Parameter	T_1	T_2	T_3	T_4	SEM	*Reference value
Packed cell volume (%)	29.00	28.50	23.00	26.00	1.35	27-45
Haemoglobin (g/dL)	9.35^{a}	8.75^{ab}	8.60^{ab}	7.10^{b}	0.37	9-15
Red blood cell ($\times 10^6$/μL)	3.21	4.29	3.56	4.29	0.20	9-15
White blood cell ($\times 10^6$/μL)	4.13	5.20	5.28	3.78	0.34	4-12
White blood cell differential						
Lymphocytes (%)	63.50	63.50	57.50	62.00	1.94	40-75
Neutrophils (%)	34.50	33.50	39.50	33.50	2.08	10-50
Monocytes (%)	2.00	1.50	1.00	2.00	0.26	0-6
Eosinophils (%)	0.50^{b}	1.50^{b}	2.00^{ab}	2.50^{a}	0.28	0-10

^{ab} Means in the same row with different superscripts are different (P<0.05)
SEM= Standard Error of Mean; *Ref. Range (Latimer *et al*., 2011).

Serum biochemicals of sheep fed vegetable and citrus waste-based silage are presented in Table 5. Serum total protein of T_1 and T_3 (P<0.05) were lower than T_2 and T_4, while albumin levels across the treatments were not different (P>0.05). Albumin level (2.63–2.93 g/dL) is similar to the range (2.65–3.07 g/dL) reported by Ayandiran *et al.* (2019) for goats and a normal range of 2.4 to 3.0 g/dL for sheep (Latimer *et al.*, 2011). The normal range of albumin levels implied that the synthetic functions of the liver were not impaired. Serum cholesterol levels among treatments were comparable (P>0.05), but T2 and T3 were significantly different (P<0.05). However, the cholesterol levels (15.39-36.93 mg/dL) in sheep were below the normal range (44-90 mg/dL) documented by Latimer *et al.*, (2011). Lower levels of cholesterol are suggestive of the absence of dyslipidaemia. Meanwhile, lower serum cholesterol, below the normal range, could be attributed to lower crude fat/ether extract content in the experimental diet and inefficient lipid synthesis, thus suggesting the need for dietary fat supplementation.

Blood urea nitrogen gives insight into protein supply status and rumen function of animals (Hess *et al.*, 2000). High serum urea nitrogen levels usually reflect inefficient utilisation of dietary nitrogen (Nousiainen *et al.*, 2004). Serum urea nitrogen (19.56-21.32 mg/dL) obtained was lower than the 55.34-72.54 mg/dL reported (Das *et al.*, 2022) in lambs fed vegetable waste silage as a replacement for maize silage, but fell within the range (10-35 mg/dL) considered as normal (Radostits *et al.*, 2000). This indicates efficient dietary amino acid metabolism, absence of urea toxicity and an actively functioning liver. The creatinine values (0.09-1.05) were similar (P>0.05) across treatments, lower than the levels (1.45-2.00 mg/dL) reported for WAD sheep (Omotoso *et al.*, 2021), and fell within the acceptable range (0.9-2.0 mg/dL) for a healthy sheep (Latimer *et al.*, 2011). This indicated that the sheep had no renal disorder. Therefore, all the biochemical parameters investigated revealed that the health status of experimental sheep fed vegetable and citrus waste silages was not compromised.

Table 5: Serum biochemicals of sheep fed citrus and vegetable waste-based silage

	Silage Treatments					
Parameter	T_1	T_2	T_3	T_4	SEM	*Reference values
Total protein (g/dL)	6.64^{b}	6.20^{b}	7.45^{a}	7.56^{a}	0.13	5.9-7.9
Albumin (g/dL)	2.93	2.63	2.66	2.67	0.07	2.4-3.0
Cholesterol (mg/dL)	26.92^{ab}	15.39^{b}	36.93^{a}	26.93^{ab}	1.99	52-76
Urea (mg/dL)	21.61	19.56	21.32	20.91	0.40	10-35
Creatinine (mg/dL)	1.05	1.05	0.90	1.00	0.04	0.9-2.0

^{abc}= Means in the same row with different superscripts are different (P<0.05)
SEM= Standard Error of Mean; *Ref. Range (Latimer *et al*., 2011).

Conclusion

Vegetables (carrots and cabbage) and citrus waste silages present quality silages that were acceptable to West African Dwarf sheep and intake had no adverse impact on their health status. However, there is a need for supplementation of the silage with protein and oil-rich feed resources. Hence, citrus and vegetable wastes should not be left to rot and pose a negative effect on the environment, but should be converted to quality ruminant feed in the form of silage.

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