Improve the nutritional value and utilization of rice straw via an ensiling process with different sources of energy and nitrogen enrichment

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ABSTRACT
Ensiled rice straw using, water (RSW), molasses plus urea, and whey (RWh) were implied to investigate the ensiling processing on palatability and nutritional value of rice straw compared to untreated rice straw (URS). Using whey resulted in a significant \( P < .05 \) progress in fermentation coefficient, and Flieg Score compared to others. Protein and water-soluble carbohydrates content increased \( P < .05 \) in RWh compared to RMU. Gas cumulative increased \( P < .05 \) with ERS compared to the incubation of URS. In-vitro organic matter degradability, neutral detergent fiber degradability, crude protein degradability, microbial protein, and metabolizable energy varied less amongst the tested ingredients. The RWH was significantly \( P < .05 \) consumed and palatable higher compared to RMU, which was more \( P < .05 \) significant than RSW. The use of either RWh or RMU has improved total digestible nutrients (TDN) compared to RSW and URS. The values of total protein, alanine aminotransferase, and glucose were higher \( P < .05 \) with ERS feeding compared to URS. The results indicate the possibility of ensiling rice straw with added either whey or molasses with urea as sources of nitrogen and energy to induce good fermentation and improve utilization of rice straw.

Introduction
Rice has a relatively large amount of residue identified as straw. Rice straw is used as part of the rations of ruminant animals (Dong et al. 2008). Van Soest (2006) reported that the high level of lignification and silicification are the important factors that restrict bacterial breakdown in the rumen. Other factors that affect its value as feed for ruminants are the slow and inadequate ruminal degradation of the carbohydrates and the low content of nitrogen, minerals, and vitamins. There are different techniques for improving the nutritive value of rice straw to enhance feed intake and digestibility. Classified broadly methods of treating rice straw are mechanical, physical, chemical, and biological (Sarnklong et al. 2010) to utilize rice straw as a ruminant feed. Unfortunately, treating rice straw with urea for raising the nutritional value, mounts from it a large amount of nitrogen, which increases \( \text{N}_2\text{O} \) emissions, which causes a detrimental effect on human health (Abo-Donia et al. 2014). On the other hand, it contributes greatly to the phenomenon of global warming that leads to undesirable climate changes.

Our hypothesis in this study, the ensiling considers one of the current techniques that can use to enhance the nutritive value and the palatability of rice straw to maximize efficient utilization, this approach is in agreement with (Cherdthong et al. 2020; So et al. 2020; Cherdthong et al. 2021). While hollow stems, low water-soluble carbohydrates (WSC), and less epiphytic lactic acid bacteria (LAB) hinder the success of this process (Cao et al. 2010). Many studies have reported using some additives to improve the fermentation quality for ensiling forage (Huisden et al. 2009; Cherdthong et al. 2021). For example, molasses or potato pulp has been used in the silage of straw (Zhang et al. 2000 and So et al. 2020) yellow corn, and sub-graded sweet potato tuber (Abo-Donia et al. 2007). The significance of bioconversion of industrial waste such as whey into value-added products through the biotechnological route has been realized (Wee et al. 2006). Whey is the liquid waste that can use as an inexpensive source of nitrogen resources, vitamins, and minerals for the cultivation of microbes such as \textit{Lactobacillus} spp. for the production of lactic acid (Yu et al. 2008). Whey can be produced at any time of the year and contains about 55/100 g of the total ingredients of milk as lactose, soluble proteins, lipids, and mineral salts, so it is now considered a valuable product rather than a waste product.

This study aimed at the simulation of fermentation which occurs during the silage making by adding some additives that play a role in overcoming the obstacles of rice straw ensiling alone and improving palatability. Also, it aimed to study the effect of ensiled rice straw (ERS) on its palatability and nutritional value as ruminant feed.

Material and methods
The care and guidance of animals for the accomplishment of the experimental plan was approved by the Research
Committee of Animal Production Research Institute (APRI), Giza, Egypt, on Animal Use (Registration, 01-02-02-37).

Whey mixes from the Ras cheese (Kefalotyri) and Domiat cheese (1:1) were collected from the Municipal laboratories for cheese production in Kafr El-Sheikh in an insulated box then examined and stored. The whey during its production, handling and storage were under hygienic conditions. Granular Urea (46.5% N) produced by Abu Qir Fertilizers Company, Alex, Egypt, and sugarcane molasses brought from a Hawamidya Sugar Factory, Giza, Egypt. Rice straw is supplied to the experimental station (Sakha) of the Animal Production Research Institute by supplier dealers.

Ensiling process of rice straw

Ensiled rice straw (ERS) was chopped into lengths of 2 - 3 cm with a fodder chopper then manually mixed with additives rich in nitrogen and energy to ensiled as follows: (i) rice straw ensiled with water (RSW), (ii) rice straw ensiled with molasses plus urea (RMU) to provide a source of energy and nitrogen of bacteria, (45 mL molasses + 5 g urea per kg rice straw) in line and (iii) rice straw ensiled with whey (RWh) which contains energy and nitrogen for the bacteria in keeping with Bautista-Trujillo et al. (2009). The humidity was adjusted to achieve 60% by using (Digital Moisture Meter TK100H, Guangdong, China) with good and continuous stirring, where the rice straws were wetted by spraying water with both RSW and RMU, while the humidity adjusts by the whey only in RWh. Rice straw was ensiling in packed out within blue drums for each of the (RSW, RSMU, and RWh) separately for 45d.

In-vitro gas production kinetics and degradability

The in-vitro technique accustomed used to evaluate ERS and answer the subsequent question, how far is it possible to use whey (as industrial waste) or molasses plus urea to ensiling rice straw? and also, evaluation of rumen fermentation kinetics, gas production, degradability on using ensiled rice straw. Four replicates per treatment for the in-vitro study were ensiled (approximately 1000 g of each treatment) into 1 L laboratory glass and stored at the ambient temperature (22°C to 28°C) after being sealed with screw tops and plastic tape. The fermentation was terminated after 45d of ensilling where the packed opened and characterized ERS. Rumen fluid was collected from three Ossimi rams before the morning feed into a Thermo flask. The procedure for in-vitro gas production was as established by Navarro-Villa et al. (2013). The rumen liquor collected was properly mixed and filtered through four layers of cheesecloth and mixed with the buffered mineral solution (Menke and Stein-gass 1988) at a ratio of 1:4 (rumen fluid to buffer, v/v). Briefly, a 0.6 g silage sample was transferred into a 100mL glass bottle incubated in 60mL of diluted rumen fluid. The gas production (GP) was measured intermittently throughout the incubation using the Reading Pressure Technique (RPT) (Hangzhou Runchen Electron Com., Hangzhou, China). Headspace gas pressure was measured at 3, 6, 12, 24, 48, 60, and 72 hr. Results of kinetic parameters of GP (mL/g DM) were fitted using the NLIN option according to France et al. (2000) as

\[ P = b \times (1 - e^{-ct}) \]

where P is the volume of GP at time t, b is the asymptotic P (mL/g DM), c is the rate of P (mL/hr), and L (hr) is the discrete lag time before initiation of P. The metabolizable energy (ME; MJ /kg DM) of samples was calculated using an equation of Menke et al. (1979) as follows:

\[ ME (MJ/kg DM) = 2.20 + 0.136 \times \text{gas volume produced} + 0.057 \times \text{CP} \]

where CP is crude protein content. Another run applied to estimated degradability of OM, CP, and NDF at 48 hr of incubation for tested ERS (4 replicates/treatment). The residual solutions were filtered by gravity, using Whatman No 4 filter paper, the sediments in bottles for determining IVCPD were used to estimate protein without drying, while the residues in the other bottles for determining IVOMD and IVNDF dried at 105°C for 24 hr. The dry residues were incinerated at 550°C for measuring IVOMD. Four bottles with no substrate added were included as blanks in each run. Microbial crude protein (MCP) productions were then calculated using the equations of Grings et al. (2005):

\[ \text{Microbial crude protein (g/kg DM)} = \text{DOM} \times 0.03217, \]

where OMD is organic matter digestibility. Metabolizable energy (ME) calculated from in-vitro gas production using the equation of Close and Menke (1986), with lipid content ignored, where:

\[ \text{ME} = 2.20 + (0.136 \times \text{gas volume produced}) + (0.057 \times \text{CP}) \]

where CP is crud protein content. The relative feed value (RFV) is an index used to rank feeds relative to the typical nutritive value of full bloom alfalfa hay, containing 41% ADF and 53% NDF on a DM basis, and having an RFV of 100, which is considered to be a standard score.

\[ \text{RFV} = (\text{DDM (DM)} / \text{DMI (BW)}) / 1.29, \]

where, DDM (digestible dry matter) and DMI (dry matter intake potential as % of body weight) were calculated from ADF and NDF, respectively as DDM (% DM) = 88.9 - 0.78 x ADF (% DM) and DMI (%BW) = 120/ NDF (% DM).

Feed intake and digestibility trial

For applying the digestibility trials, one ton of each ensiling rice straw was packed out as the previous description for (RSW, RSMU, and RWh) in blue cylindrical drums (500 L), and then maintained for 45d. Digestibility trials were applied to investigate the attractability and palatability of ERS and assessment nutritional evaluation of tested ERS. Twelve adult Ossimi rams with average live body weight (52.08 ± 0.44 kg LBW) selected from the sheep flock kept at Sakha Research Station were allotted, according to a randomized complete block, to twelve cages into four similar groups, then assigned on four tested diets for (28d periods, 23d adaption period and 5d for...
samples collection) to determine digestibility. The CFM was fed twice daily at 06:30 and 18.30 hr for maintenance requirements according to NRC (1985). After finished of CFM, tested ERS was offered ad libitum, where the first group fed URS, the second group fed RSW, the third group fed RMU, and the fourth group fed RWh. The weight of feed offered, refused, and feces were recorded, and a 10% sample individually homogenized was collected daily in the morning during each 5d collection period. All samples were oven-dried at 55°C for at least 72 hr, ground to pass through a 1-mm screen, and stored until analyses. The residuals were analysed to determine the actual feed intake of different nutrients. Relative palatability was calculated as follows (FI/FO × 100). Over 24 hr, eating, chewing and rumination behaviour in the different groups were visually tracked by a pre-trained team according to the description of Minervino et al. (2014).

Blood samples were collected in the morning from the jugular vein of each animal before access to feed on the external jugular vein into vacutainers on the last day of each experimental period. The collected blood samples were centrifuged at 4000 rpm/15 min to separate the serum then stored at −18°C until analysis.

Samples and analysis

The colour of ERS was measured by using a chart in which they compare, the sensory evaluation was made by committee members (evaluators) according to Manaye et al. (2018). A subsample was blended with distilled H₂O at a ratio of 1:3 and stored at 4°C macerating for 24 hr to obtain the cold extract by filtered through four layers of cheesecloth according to Zhao et al. (2019), then, the supernatant was wont to determine pH, ammonia-N (NH₃-N), lactic acid and organic acids. The pH meter (Hanna, model HI 8424) is used for major pH. The NH₃-N concentration of ERS was estimated as described by Weatherburn (1967). Samples of Acetic, Propionic, and Butyric concentrations were analysed by gas–liquid chromatography as described by Li and Meng (2006) using column (HPINNO-WAX,30m_0.250mm_0.25 mm). The lactic acid concentration was measured by the method of James (1995). The buffering capacity (BC) according to Playne and McDonald (1966). Fermentation coefficient (FC) is consistent with the formula of Yitbarek and Tamir (2014). Flieg’s Score was calculated as mentioned by Kilic (1986).

Flieg’s score = 220 + (2 × % DM - 15) × 40 × pH

The counts of epiphytic microorganisms in ERS were immediately determined in fresh samples. The plate counting of microorganism populations and the colony-forming unit (cfu) were used for the enumeration.

The samples (10 g) homogenized with 90 mL sterilized saline solution, were serially diluted (8.50 g/L NaCl) from 10⁻¹–10⁻⁶. Counted of the LAB, aerobic bacteria, moulds, and yeasts on MRS agar medium, nutrient, and potato dextrose at 37°C for 2–3d, respectively. Yeasts and moulds were enumerated according to VDLUFA (2012) methods 28.1.1 and 28.1.4.

Composite feed, ERS, and feces samples were analysed DM in keeping with AOAC (2012). Crude protein (CP) was determined in fresh samples of feed ERS and feces. Total nitrogen (TN) was resolute by Kjeldahl nitrogen analyser (Kjeltec 8200; FOSS, Höganäs, Sweden), and therefore the CP was calculated as TN×6.25. Ash was measured by incinerating during a muffle furnace at 550°C for 4 hr. Neutral detergent fibre (NDF) assayed with the addition of a heat-stable amylase but without sodium sulphate and acid detergent fibre (ADF) procedures were performed according to Van Soest et al. (1991).

Statistical analysis

All data were subjected to analysis of variance using a general linear model (GLM) procedures of the Statistical Analysis System Institute (SAS Institute, 2009). Differences between treatment means were determined by Duncan’s multiple range test methods (Duncan 1955). Differences among means with P < .05 were accepted as representing statistically significant differences.

Results and discussion

According to the proposed application of chemo-physical characteristics for ensiling quality, the evaluation of ERS is considered an excellent standard of fermentation (Table 1). The degree of colour obtained (Yellowish to light-yellow) in the present study was close to the original colour of rice straw before ensiling which indicates the success and quality of ensiled rice straw. Good ensiled materials usually preserve the original colour of the pasture or any forage (Odugwu et al. 2007). Bolsen et al. (1996) reported that any excessive heat production can result in a Maillard or browning reaction which can reduce the digestibility of protein and fibre components. The texture and aroma of the ERS were firm and pleasant which was expected to succeed ensiled materials, and the temperature of ERS was 25.65: 26.40°C.

As mentioned by Kung and Shaver (2001) the texture of the ERS was firm which was expected to be the most suitable texture such as a good ensiled material. Ensiled rice straw was pleasant and pleasant-fruity aroma which is an indication of well-made ensiled materials, Kung and Shaver (2001) reported that pleasant smell is accepted for good or well-made silage. The temperature of ERS was 25.65: 26.40°C and compatible with the range (25–27°C) obtained by Babayemi (2009). Temperature is one of the essential factors affecting silage colour. Muck (2010) reported that the temperature of fermenting forage varying from 27 to 38°C was presumed to produce excellent silage. The addition of whey resulted in a significant (P < .05) increase in lactic and acetic acid compared to adding molasses and urea, which was significantly (P < .05)
higher than adding water only. The whey improves the viability of lactic acid bacteria (LAB) due to enhancing the buffering capacity of the culture medium (Shafaghat et al. 2010; Bautista-Trujillo et al. 2009). While the increase in acetic acid is due to the presence of sources of nitrogen and carbohydrates in both RFV and RMU, which increases the fermentation of carbohydrates and fibre in silage (Zhao et al. 2019; Cao et al. 2010). The ratio of lactic acid to acetic did not change (P > .05) significantly.

In the present study, the values of pH ranging from 4.06 to 4.11 and did not differ (P > .05) significantly among types of ERS, where the classified values of pH for good ensiled materials range from 3.5 to 5.5 (Meneses et al. 2007). The nitrogenous compounds suggestive of an appropriate fermentation, the adjustments in their distribution might have happened during the ensilage as reported by Ventura-Canseco et al. (2012). The same trend of the fermentation coefficient (FC) was shown. Ammonia-N concentration, buffering capacity (BC), and Flieg Score significantly (P < .05) decreased in RWh then RMU followed by RSW. Ether extract content was significantly (P < .05) lower with RWh than that of RSW by 11.36%.

Results for the chemical composition of URS and ERS were expected as reported by Keady (1996); Li et al. (2010) who was added glucose as a source of carbohydrate to ensiling rice straw. Molasses additives reduce nitrogen losses in the ensiled materials (Cao et al. 2010; Bautista-Trujillo et al. 2009). Regarding EE content, Mariotti et al. (2020) reported that the content of EE increases when ensiled alfalfa, it is possible that the increased viability of organisms so reflected on microbial mass that is active in silage causes an increase in the fat content (Li et al. 2010). On the contrary, the content of protein, and WSC significantly (P < .05) increased in RWh compared to RMU which was significantly (P < .05) higher than its content in RSW. The ash content was higher in ERS than URS. This increase in ash content may be due to the molasses and whey added, the molasses containing 0.12 mg L\(^{-1}\) ash (Shafaghat et al. 2010), while Outilen et al. (2010) reported an average of 0.44 g 100 g\(^{-1}\). Many studies pointed out that either molasses or whey as an additive have been used as a stimulant to increase the supply of fermented carbohydrates to promote the growth of fermented microorganisms LAB and yeasts (Cao et al. 2010; Saeed and Abo-Ellul 2018; Mariotti et al. 2020).

### Table 1. physico-chemical characteristics of different types of ERS.

| Item                | RSW | RMU | RWh | ±SE  
|---------------------|-----|-----|-----|------
| **Physical characteristics** |     |     |     |      
| Colour              | Yellowish | light-yellow | light-yellow | –       
| Aroma               | pleasant | pleasant-fruity | pleasant-alcoholic | –       
| Texture             | Firm    | Firm    | Firm    | –       
| Temperature (°C)    | 26.40   | 26.19   | 25.65   | 0.565  
| pH                  | 4.11    | 4.07    | 4.06    | 0.014  
| Fermentation        |         |         |         |        
| LA (mmol/L)         | 35.94\(^{a}\) | 39.63\(^{b}\) | 43.44\(^{a}\) | 0.777  
| AC (mmol/L)         | 11.99\(^{a}\) | 12.87\(^{a}\) | 13.56\(^{a}\) | 0.124  
| Bu (mmol/L)         | 1.69\(^{a}\) | 1.42\(^{a}\) | 1.56\(^{b}\) | 0.020  
| LA/AC               | 2.99    | 3.39    | 3.65    | 0.308  
| NH\(_3\)-N (g/kgTN) | 3.13\(^{b}\) | 3.80\(^{b}\) | 3.80\(^{a}\) | 0.130  
| Buffering capacity (mEq/kg DM) | 12.27\(^{ab}\) | 12.88\(^{a}\) | 13.01\(^{a}\) | 0.126  
| Fermentation coefficient | 38.20\(^{b}\) | 38.82\(^{b}\) | 38.97\(^{b}\) | 0.035  
| Flieg Score         | 98.56\(^{b}\) | 100.13\(^{ab}\) | 100.61\(^{a}\) | 0.589  
| **Microbes, (log\(_{10}\) cfu g\(^{-1}\) FM)** |  |  |  |  
| Total count bacteria | 9.10\(^{b}\) | 9.37\(^{ab}\) | 9.65\(^{a}\) | 0.161  
| Lactic acids bacteria | 1.13\(^{b}\) | 2.03\(^{b}\) | 3.02\(^{a}\) | 0.103  
| Aerobic bacteria    | 5.35\(^{a}\) | 5.51\(^{ab}\) | 5.68\(^{a}\) | 0.095  
| Moulds              | 4.12    | 3.92    | 4.00    | 0.075  
| Yeasts              | 3.76\(^{b}\) | 4.09\(^{b}\) | 4.00\(^{b}\) | 0.043  

\(^{a,b}\)=Means within rows with unlike superscript differ significantly (P < .05). Each value represents the mean of four replicates.

| RSW, ensiled rice straw with water; RMU, ensiled rice straw with molasses plus urea; RWh, ensiled rice straw with whey. LA, Lactic acid; AC, Acetic acid; Bu, Butyric acid. |

### Table 2. Chemical composition of Rice straw and different types of ERS.

| Treat          | DM  | OM  | CP  | EE   | Ash | NDF | ADF | WSC  |
|---------------|-----|-----|-----|------|-----|-----|-----|------|
| **Ensiling rice straw** |     |     |     |      |     |     |     |      |
| RSW           | 36.41 | 81.52\(^{a}\) | 3.42\(^{c}\) | 0.44\(^{a}\) | 18.48\(^{c}\) | 62.61\(^{b}\) | 42.34\(^{a}\) | 2.73\(^{a}\) |
| RMU           | 36.45 | 80.00\(^{b}\) | 4.79\(^{b}\) | 0.41\(^{ab}\) | 11.00\(^{a}\) | 60.54\(^{b}\) | 41.03\(^{b}\) | 3.83\(^{b}\) |
| RWh           | 36.50 | 78.67\(^{c}\) | 6.50\(^{a}\) | 0.39\(^{b}\) | 21.33\(^{a}\) | 58.44\(^{b}\) | 39.60\(^{c}\) | 4.02\(^{a}\) |
| ±SE           | 0.035 | 0.219 | 0.049 | 0.011 | 0.219 | 0.262 | 0.179 | 0.034 |

\(^{a,b}\)=Means within the column with unlike superscript differ significantly (P < .05). URS, untreated rice straw; RSW, ensiled rice straw with water; RMU, ensiled rice straw with molasses plus urea; RWh, ensiled rice straw with whey. Except for URS, each value represents the mean of four replicates.

DM, dry matter; OM, organic matter; CP, crude protein; EE, Ether extract; NDF, neutral detergent fibre; ADF, neutral detergent fibre.
**In-vitro gas production and degradability:**

The results in Table 3 revealed the gas accumulation (GV) and rate of release. Gas kinetics was associated with IVOMD, IVNDFD, IVCPCD, and ME, where the RWh had the highest GV followed by those of RMU. Gas cumulative increased (P < .05) significantly with ERS compared to the incubation of URS, except RSW was significantly lower than RMU and RWh. In-vitro gas production rates concerning ERS as an illustration in Figure 1, indicate an increase in GP released with RMU and RWh compared to URS and RSW. The increased gas release was associated with the improvement degradation of OM and NDF which resulted from the increased activity of microorganisms.

The volume of gas accumulation (GV) and rate of release are mightily close results to the values found in a study by Sniffen et al. (2006) who reported that improve fibre degradation leads to an increase in gas accumulation as well as its release rate. Based on the previous studies, the enlargement in ME may be related to providing energy and nitrogen sources for ERS (Ventura-Canseco et al. 2012; ZoBell et al. 2005). Adding whey enhanced the ERS than adding molasses plus urea. This may be due to the availability of some nutrients in whey that help microorganisms to accomplish higher rates for better-quality fermentation. These results are consistent with Zhao et al. (2019) who used molasses to ensiling rice straw, and Bautista-Trujillo et al. (2009) used whey to ensiling corn stalks. The values of ME varied less amongst the tested ingredients (4.94; 6.25 MJ/kg DM) for URS and RWh, respectively. The ME content of ERS improved from 5.10 to 6.25 MJ/kg DM compared to URS. The same trend of IVOMD, IVNDFD, IVCPCD, and MP was shown with URS, RSW, RMU, and RWh. The lowest (P < .05) RFV was from URS (45.52), while the highest (P < .05) were obtained from RMU and RWh (61.89 & 66.68), respectively. These values are somewhat good when compared to standard good quality alfalfa hay which is considered to have 100% RFV. The RFV value of RSW was moderately improved compared to URS but lower than that add energy and nitrogen source.

**Table 3.** Gas kinetic, and degradability of different types of ERS.

| Item             | URS  | RSW  | RMU  | RWh  | ±SE  |
|------------------|------|------|------|------|------|
| Gas prod         |      |      |      |      |      |
| b (ml/ g DM)     | 34.07c | 37.86b | 41.81a | 42.88a | 0.863 |
| c (ml h⁻¹)       | 0.027ab | 0.027b | 0.040a | 0.040a | 0.001 |
| ME (MJ/kg DM)    | 4.94d | 5.10c | 6.06b | 6.25a | 0.038 |
| Degradability (%)|      |      |      |      |      |
| IVOMD (%)        | 32.22c | 38.34b | 40.82a | 41.89a | 1.022 |
| IVNDFD (%)       | 28.36b | 30.91b | 40.66a | 41.66a | 0.399 |
| IVCPCD (%)       | 27.92c | 35.85b | 43.55a | 47.03a | 1.766 |
| MP (g/kg⁻¹ DM)   | 1.04a | 1.14b | 1.30a | 1.35a | 0.033 |
| RFV              | 45.52d | 56.98c | 61.89b | 66.68a | 0.525 |

abc Means within rows with unlike superscript differ significantly (P < .05). Each value represents the mean of four replicates.

URS, untreated rice straw; RSW, ensiled rice straw with water; RMU, ensiled rice straw with molasses plus urea; RWh, ensiled rice straw with whey; IVOMD, Organic matter degradability; IVNDFD, Neutral detergent fibre degradability; IVCPCD, Crude protein degradability; ME, Metabolizable energy (MJ/kg DM); MP, Microbial protein (g/kg DM); RFV, Relative feeding value.

**Feed consumption and nutrients digestibility**

All nutritional components differed in the experimental diets as a result of their content in URS or ERS as well as the amount of feed consumed as shown in Table 4. The content of DM, OM, NDF, ADF, Cell, and hemicellulose significantly (P< .05) decreased, while the feed content of CP, ash and WSC increased. The feed intake of the tested diets significantly (P<.05) increased with fed ERS than that fed URS. The total DM intake (TDI) increased (P<.05) significantly with the diet that contained RWh than that contained RMU, which was significantly (P<.05) higher than that contained RSW. The ERS was more consumed by animals compared to URS Despite the same quantities of URS and ERS offered. In the current study, the RWh was significantly (P<.05) consumed higher by animals compared to that RMU, which was more (P<.05) significant than RSW. Increased feed consumption was related to the palatability which significantly (P<.05) increased with ERS compared to URS, these results are in agreement with Kim et al. (2014); Huuskonen (2017). The palatability of RWh, RMU, and RSW increased by 36.67%, 28.44%, and 18.04% than URS, respectively. Eating, ruminating, and chewing (min/d) were significantly (P> .05) decreased with ERS compared to URS. Eating, ruminating, and total chewing time (min/d) were reduced when feeding on RWh, while RMU and RSW showed no significant differences between them. (Kim 2006) reported that feed DM
intake increases linearly as feed particle size decreases. Other reasons for increased feed intake may be due to favourable palatability and/or high digestibility of based silage (Kim et al. 2014). Differences between our findings and those obtained from the previous studies (Huuskonen 2017) can be attributed to a stimulatory effect of ERS on the intake, where added whey into ensiled rice straw (RWh) improved quality more than addition molasses with urea (RMU), which was the turn better than ensiled rice straw with water (RSW). Similar results have been found by other authors (Ventura-Canseco et al. 2012; Huisden et al. 2009). In line with our findings, Manyawu et al. (2003) show that high palatability (or preference) can lead to high intake. In addition, research by Buchanan-Smith (1990) shows that intake tends to be high in well-preserved silage. The differences in the intake and preference of the silages are likely to be a reflection of differences in the DM content (Manyawu et al. 2003). Kim et al. (2014) found that changes in intake are related to the DM content of silages. Increased spending time of eating, rumination, and chewing are related to the content of NDF and ADF (Abo-Donia et al. 2007; Hafez et al. 2015). The work of Kim et al. (2014) reported that ensiling materials lead to a decrease in spending time for eating, rumination, and chewing. Who attributed that to, the fermentability of silage fibre, starch, and protein, with fermentation end products, influence dairy cattle feeding behaviour, and DMI. The digestibility coefficients of the nutrient components of the tested diets used in the digestion trials exposed a higher significant (p < .05) difference in feeds containing ERS as shown in Table 5. Interestingly, ensiled RWH and RMU had the highest DM, OM, CP, EE, NDF, and ADF digestibility values and these values were significant (P < .05) higher than those of RSW. Improvements in nutrient digestibility of silage were reviewed by Ventura-Canseco et al. (2012); ZoBell et al. (2005) who reported that silages contain appropriate levels of energy and nitrogen leading to improvement in nutrients digestibility. A follow-up trial of a similar design by Nkosi and Nkosi (2010) stated that carbohydrate fermentability influences ruminal fermentation and end product concentrations and, consequently, feeding behaviour and DMI, so that reflects on nutrients digestibility level. Furthermore, the use of either RWH or RMU has improved total digestible nutrients (TDN) compared to RSW and URS. All ERS types used increased (P < .05) significantly the DCP values compare to those that were not un-ensiled. In addition, the data pointed out that the values of DCP when feed RWH showed significantly (P < .05) superiority than that of feed RMU, which in turn was superior to that of RSW.

Increase digestibilities of DM and OM could be due to a rise in digestibility of ADF and NDF (Anil et al. 2000) and changes in protein and cell wall components of ERS (Abo-Donia et al. 2007; Hafez et al. 2015). Abo-Donia et al. (2014) reported that biological treatment of roughages could increase the digestibility coefficients for most nutrients and thus their feeding values as TDN and DCP compared with untreated materials. Suitable treatment techniques in combination with nutrient supplementation could result in improved utilization of rice straw with better benefits (Trach 1998).

### Blood constituents

Data of blood constituents are presented in Table 6. The results indicated that most blood parameters were not significantly affected by tested silages incorporated in the experimental rations (URS, RSW, RMU, and RWH). No significant changes were shown in concentrate values of albumin, globulins, SGOT, urea, and creatinine in the blood of sheep fed ERS or URS. The values of albumin, globulins, SGOT, urea, and creatinine in the blood of sheep fed either ERS or URS were within the normal range reported by (Djuricic et al. 2011). While the values of total protein, SGPT, and glucose were significantly (P < .05) higher with ERS feeding compared

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**Table 4. Chemical analysis of feed consumption, body weight, feed intake, palatability, and feeding behaviour.**

| Treat | URS | RSW | RMU | RWh | ±SE |
|-------|-----|-----|-----|-----|-----|
| Chemical composition | | | | | |
| DM (%) | 90.26<sup>a</sup> | 52.27<sup>b</sup> | 51.37<sup>c</sup> | 50.75<sup>d</sup> | 0.104 |
| OM (%) | 86.65<sup>b</sup> | 80.12<sup>c</sup> | 82.19<sup>d</sup> | 82.09<sup>a</sup> | 0.159 |
| CP (%) | 1.64<sup>b</sup> | 1.59<sup>c</sup> | 1.70<sup>d</sup> | 1.69<sup>a</sup> | 0.186 |
| EE (%) | 1.18<sup>a</sup> | 1.10<sup>b</sup> | 1.05<sup>c</sup> | 1.00<sup>d</sup> | 0.009 |
| Ash (%) | 12.35<sup>a</sup> | 12.01<sup>b</sup> | 12.73<sup>c</sup> | 12.57<sup>d</sup> | 0.133 |
| NDF (%) | 54.09<sup>a</sup> | 50.71<sup>b</sup> | 49.93<sup>c</sup> | 48.87<sup>d</sup> | 0.210 |
| ADF (%) | 35.02<sup>a</sup> | 33.09<sup>b</sup> | 32.63<sup>c</sup> | 31.97<sup>d</sup> | 0.154 |
| Cellulose (%) | 19.34<sup>a</sup> | 18.22<sup>b</sup> | 18.20<sup>b</sup> | 18.06<sup>b</sup> | 0.110 |
| Hemicellulose (%) | 19.07<sup>a</sup> | 17.62<sup>b</sup> | 17.29<sup>c</sup> | 16.90<sup>d</sup> | 0.186 |
| WSC (%) | 2.97<sup>a</sup> | 3.95<sup>b</sup> | 4.66<sup>c</sup> | 4.76<sup>d</sup> | 0.026 |
| Feed intake, palatability, and Feeding behaviour of ERS | | | | | |
| Total Feed Intake (kg/h/d) | 1.506<sup>a</sup> | 1.682<sup>b</sup> | 1.788<sup>c</sup> | 1.875<sup>d</sup> | 0.009 |
| Feed Offer (kg) | 1.562<sup>a</sup> | 1.559<sup>b</sup> | 1.562<sup>c</sup> | 1.566<sup>d</sup> | 0.011 |
| Actual Feed (kg) | 0.996<sup>a</sup> | 1.173<sup>b</sup> | 1.278<sup>c</sup> | 1.365<sup>d</sup> | 0.010 |
| Feed Residues (kg) | 0.567<sup>a</sup> | 0.386<sup>b</sup> | 0.283<sup>c</sup> | 0.202<sup>d</sup> | 0.015 |
| Palatability (%) | 63.75<sup>a</sup> | 57.25<sup>b</sup> | 51.25<sup>c</sup> | 48.87<sup>d</sup> | 0.839 |
| Eating (min/day) | 231<sup>a</sup> | 210<sup>b</sup> | 202<sup>c</sup> | 195<sup>d</sup> | 2.651 |
| Ruminating (min/day) | 458<sup>a</sup> | 498<sup>b</sup> | 496<sup>c</sup> | 495<sup>d</sup> | 3.756 |
| Chewing (min/day) | 907<sup>a</sup> | 841<sup>b</sup> | 835<sup>c</sup> | 823<sup>d</sup> | 4.248 |

**Table 5. Apparent digestibility and nutritive value of different tested diets.**

| Treat | URS | RSW | RMU | RWH | ±SE |
|-------|-----|-----|-----|-----|-----|
| Apparent digestibility coefficients (%) | | | | | |
| DM (%) | 51.20<sup>a</sup> | 56.15<sup>b</sup> | 61.52<sup>c</sup> | 63.67<sup>d</sup> | 1.181 |
| OM (%) | 52.07<sup>a</sup> | 59.18<sup>b</sup> | 63.18<sup>c</sup> | 65.29<sup>d</sup> | 1.341 |
| CP (%) | 42.67<sup>a</sup> | 53.95<sup>b</sup> | 54.68<sup>c</sup> | 57.04<sup>d</sup> | 1.128 |
| EE (%) | 52.90<sup>a</sup> | 61.55<sup>b</sup> | 64.32<sup>c</sup> | 66.31<sup>d</sup> | 1.297 |
| NDF (%) | 42.91<sup>a</sup> | 49.07<sup>b</sup> | 53.00<sup>c</sup> | 54.19<sup>d</sup> | 0.839 |
| ADF (%) | 36.70<sup>a</sup> | 43.02<sup>b</sup> | 45.47<sup>c</sup> | 46.35<sup>d</sup> | 0.832 |
| Nutritive value (%) | | | | | |
| TDN (%) | 45.90<sup>a</sup> | 48.26<sup>b</sup> | 52.77<sup>c</sup> | 54.37<sup>d</sup> | 1.032 |
| DCP (%) | 2.87<sup>a</sup> | 3.55<sup>b</sup> | 4.10<sup>c</sup> | 4.85<sup>d</sup> | 0.004 |

abcdMeans within rows with unlike superscript differ significantly (p < .05). Each value represents the mean of four replicates. URS, untreated rice straw; RSW, ensiled rice straw with water; RMU, ensiled rice straw with molasses plus urea; RWH, ensiled rice straw with whey.
Table 6. Blood metabolites of sheep that affected with feeding on different experimental diets.

| Treat          | URS   | RSW   | RMU | RWh | ±SE |
|---------------|-------|-------|-----|-----|-----|
| Total protein (g/dL) | 6.06b | 6.11ab | 6.14a | 6.17a | 0.025 |
| Albumin (g/dL)   | 3.06  | 3.11  | 3.13 | 3.06 | 0.087 |
| Globulins (g/dL) | 2.99  | 3.00  | 3.01 | 3.11 | 0.071 |
| SGOT (IU/L)      | 37.84 | 36.80 | 36.80 | 38.26 | 0.594 |
| SGPT (IU/L)      | 15.91b | 16.84ab | 17.27a | 17.18a | 0.360 |
| Urea (mg/dL)     | 13.99b | 14.09ab | 15.38a | 15.39a | 0.185 |
| Glucose (mg/dL)  | 58.24 | 58.98 | 63.74a | 65.23a | 0.283 |
| Creatinine (mg/dL) | 1.52 | 1.53 | 1.65 | 1.53 | 0.064 |

abcMeans within rows with unlike superscript differ significantly (p < 0.05). Each value represents the mean of four replicates. URS, untreated rice straw; RSW, ensiled rice straw with water; RMU, ensiled rice straw with molasses plus urea; RWh, ensiled rice straw with whey. SGOT, Aspartate aminotransferase and SGPT, Alanine aminotransferase.

to URS, except total protein, SGPT with feeding RSW. This is supported by the findings of Hafez et al. (2015) who reported that total protein, SGPT, and glucose concentrations were not affected with feeding ensiled rice straw treated by either whey or molasses plus urea when added lactic acid bacteria. The results did not exceed normal values in the blood and thus there was no negative impact on the health of animals. Generally, the values obtained of blood constituents indicated the normal physiological and healthy status of animals fed an experimental diet containing either ERS or URS.

Conclusion

The results in the current study indicate the possibility of benefiting from an ensiling technique of rice straw by adding milk whey or sugarcane molasses plus urea to raise the nutritional value and improve palatability, feed consumption, and digestibility. Despite ensiling rice straw with added whey was better than ensiled with molasses plus urea, however, the results recommend that any of these additives can be used to improve the utilization of rice straw.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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