

INFLUENCE OF CO-ENSILING REHYDRATED RICE STRAW WITH PRICKLY PEAR FRUIT PEELS FEEDING ON DEGRADABILITY, DIGESTIBILITY, AND NUTRITIVE VALUE FOR SHEEP

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SUMMARY

This study examines ensiled rice straw (ERS) with three levels of prickly pear fruit peels (PPP, w/w), 100, 150, and 200 kg per ton rice straw (RS), and added 5 kg of urea. Corn stalks ensiled with 25 kg of molasses per ton and 5 kg of urea was used as a control (CS). In a 4×4 Latin square experiment, 16 Ossimi rams (61.4±0.16 kg) were randomly assigned into four equal groups. The values of lactic acid, volatile fatty acids (VFA-s) and lactic acid bacteria (LAB) count were significantly ($P < 0.05$) decreased with increasing PPP in ERS, while the values of pH and NH₃-N were decreased.

The values of VFAs and LAB count of ERS improved compared to CS, while pH and NH₃-N were decreased ($P < 0.05$). No mold was detected in the tested silages. While neutral detergent fiber (NDF), acid detergent fiber (ADF), and total carbohydrates (TCH) values were decreased in ERS with increasing levels of PPP, the ash was significant ($P < 0.05$) increased. Dry matter recovery (DMR) values were ($P < 0.05$) higher with ERS than CS. There was no difference among ERS in terms of PPP levels for cumulative gas production (GP) up to 72 hours of incubation. Increased IVOMD, IVNDFD, and IVCPD values were associated with increased ($P < 0.05$) feed intake of ERS. Digestibility of DM, OM, CP, NDF, and ADF increased ($p < 0.05$) with the increase of PPP in ERS; which was reflected in the increase of TDN and DCP. The increased PPP level in ERS increased N-retention ($P < 0.05$). The TVFAs, acetate, bacteria number, and protozoa were increased ($P < 0.05$) in the rumen of sheep with increasing PPP in ERS, while NH₃-N values were decreased. No significant differences were shown in globulin, ALT, and AST in sheep blood plasma, while glucose was increased ($P < 0.05$) with increasing PPP level in ERS. Also, the concentration of urea and creatinine were decreased. The values for hemoglobin, erythrocytes, white blood cells, and PCV followed the same trend. Fermentation characteristics of ensiled rice straw with the inclusion of PPP were improved and can be recommended as a feed source for sheep.

Keywords: *Ensiled rice straw, prickly pear fruit peels, degradability, digestibility, nutritive value and sheep.*

INTRODUCTION

Rice is considered one of the main cash crops in Egypt, the cultivated area is 404678 - 607017 ha producing 3.2 - 3.5 million tons of straw. Few attempts were made to combine this huge amount with other ingredients containing nutrients that rice straw (RS) lacks to produce a new alternative feed for livestock (Abo-Donia *et al.*, 2022).

Moreover, El-Sheikh *et al.* (2020) suggested that the fermentation process of ERS is considered a suitable technique to improve feed consumption. The important element affecting the ensiling quality is the provision of nutrients to support microbial activity, especially the fermented energy source (Abo Donia *et al.*, 2018). The content of soluble carbohydrates mainly in PPP is a good source of energy (Morshedy *et al.*, 2020), but if urea is added as a nitrogen source (Abo-Donia *et al.*, 2018), that will reflect on the nutritive value (NV) of ensiling straw.

Prickly pear cultivation has spread as a fresh edible fruit in Egypt (El-Samahy *et al.*, 2006; El-Neney *et al.*, 2019, and Morshedy *et al.*, 2020), with an entire production of almost 31671 tons (EAS 2012). The

whole fruit of a prickly pear usually weighs from 100 to 200 g and contains a thick peel representing around 28% to 50% of the fruit (Todaro *et al.*, 2020), usually contains a high percentage of sugar, reaching more than 10% of the whole weight (El-Neney *et al.*, 2019). Close to 14,252 tons of peel are annually produced and cause an environmental problem when discarded. Due to their higher fermentability, these amounts are difficult to conserve, therefore leading to a great desire to benefit them via safe disposal (Morshedy *et al.*, 2020). But in the other hand, the high content of bioactive compounds makes them convenient as a nutraceutical and functional ingredient in some feed preparations (El-Samahy *et al.*, 2006, and El-Neney *et al.*, 2019). Studies of using RS, suggest that ensiling RS with some materials rich in soluble carbohydrates enhances their utilization (Abo-Donia *et al.*, 2022). Consequently, this study scrutinized ensiled RS incorporated with PPP rich in soluble carbohydrates and enriched with urea to overcome the problems of using either of them separately and enhance their utilization in feeding ruminants.

MATERIALS AND METHODS

The present study was conducted at the Animal Production Department, Faculty of Agriculture, Menoufia University, Egypt in compliance with Menoufia University guidelines for dealing with animals in scientific research, with the approval of the Ethics Committee, (the Institutional Animal Care and Use Committee- Menoufia University (IACUC) (Reference No. MUFAG/F/AP/2/23). The study was conducted in accordance with the cooperation protocol between the Animal Production Research Institute (APRI), the Agriculture By-Product Utilisation Research Department, Dokki, Giza governorate, Egypt and the Faculty of Agriculture, Menoufia University, the Animal Production Department (Reference No. 2429.22.2019). Laboratory for Animal Nutrition, department of Animal Production, Faculty of Agriculture at Ain Shams University, Egypt completed a part of the chemical analysis.

Ingredients collection and handling:

Green corn stalk (without ears of corn, CS) was collected from farmers' fields in Shebeen El-Kom district, and prickly pear fruit peels (*Opuntia ficus-indica L.*) (PPP) were bought from fig merchants in the Sadat district in plastic drums on the same ensiling day ; both districts belong to Menoufia Governorate (30° 31' 12" N, 30° 59' 24" E). Dried rice straw (RS) was obtained from Gharbia Governorate (30° 52' 1.2" N, 31° 1' 40.8" E) and chopped into 1.5 to 2 Cm lengths.

Co-ensiling technique of experimental materials:

After removing mature ears of corn (cobs) at harvest, the stalks were left to wilt overnight at a target DM level of 30–40% and then chopped for 2-3 cm for ensiling as a control (CS). Urea (5 kg) was dissolved in 10 L of fresh water and then mixed with sugar cane molasses (25 kg) per ton of CS, according to El-Sheikh *et al.* (2020). In contrast, exactly 5 kg of urea were well dissolved in 460, 391, and 345 liters of fresh water and distributed on each ton chopped paddy RS (90.13% DM basis) lengthed by 2-3cm. The PPP (29.54%, DM basis) was supplemented by low, medium, and high levels (100, 150, and 200 kg/pile) as fresh (w/w) for RSPL, RSPM, and RSPH, respectively. Then, each pile was inoculated with a 100 µL diluted LAB (*L. plantarum*) solution per 100 gram of fresh matter (FM) to obtain the appropriate application rate of 10^9 cfu/mL⁻¹. The four experimental piles were separately ensiled on the ground surface (on plastic mats) in a shady place where they were pressed by tractors and covered well with a 200-micron plastic cover, then covered with a layer of soil 20 cm thick, and tyres were placed up. Four laboratory glass jars (capacity, kg) were filled from each pile and then pressed, sealed well, and left for 45 days in the laboratory at room temperature. At the end of the ensiling period, the jars were opened for assessments of physical and fermentation characteristics and *in vitro* studies. Counting of lactic acid bacteria and mould detection were also done. The main piles were opened at the same time for *in vivo* trials, and samples were also taken for analysis. For the purpose of measuring DM recovery (DMR), four homogenised samples from the pre-ensiling and post-ensiling periods (one from each pile separately) were brought to the laboratory in an ice tank.

Kinetics of in-vitro gas production:

Rumen contents (50% solids, 50% liquids) were collected 4 h after the morning feeding (11:00 h) from three cannulated Osimi rams, which had free access to high-quality hay, *Trifolium alexandrinum* (berseem), and water. The rumen liquor (RL, pH of 6.12) was properly mixed in a thermos flask with

pushing CO₂ to minimize changes in microbial populations and to avoid O₂ contamination, then immediately transferred to the laboratory and kept at 39 °C in a water bath. Rumen fluid was combined with the buffered mineral solution of Goering and Van Soest (1970) at a ratio of 1:3 (rumen fluid to buffer, v/v) after being filtered through four layers of cheesecloth. Dry ensiled samples (600 mg) were transferred to a 100-mL glass vial (four vials per sample), and 60 mL of inoculum was dispensed per vial, then flushed with oxygen-free CO₂ to measure gas production (GP). After loading, each vial was immediately covered with a 14-mm butyl rubber stopper and an aluminium crimp cap that had been warmed in an incubator to 39°C. To adjust for gas release and fermentation residues that came directly from the inoculum, four replication vials of ruminal fluid plus buffer on their own without substrate were used. The GP was measured by inserting a 23-gauge (0.6-mm) needle attached to a reading pressure technique (RPT) model (Digital indicator, Hangzhou Runchen Electron Com., Hangzhou, China) connected to a visual display. Incubation times of 6, 12, 24, 48, 60, and 72 hours were used to measure the headspace gas produced during substrate fermentation. Once the transducer was removed, the needle remained in place to allow venting. Once a tray of culture vials had been measured, the process was repeated. Following the removal of all needles, the flasks were mixed and put back in the incubator after being swirled. Volume estimations were generated using pressure values that had been adjusted for the volume of OM that had been incubated and the gas emitted from the standard. Results of the kinetic parameters of GP (mL/g DM) were fitted using the NLIN option according to France *et al.* (2000) using the following model,

$$Gv = b \times (1 - e^{-c(t-L)})$$

Where Gv is the volume of GP at time t, b is the asymptotic Gv (mL/g DM), c is the rate of Gv (mL/hr), and L (hr) is the discrete lag time before initiation of Gv.

In-vitro degradability of DM, CP, and NDF:

Another run was applied to measure the degradability of DM, CP, and NDF, 600 mg were inserted into a 100-mL glass vial (four vials for every sample, 4 replicates per each parameter), inoculated (60 mL per vial), and flushed with oxygen-free CO₂. Each run comprised four bottles as blanks, which had no substrate added to them. After 48 h of incubation, 20 ml was filtered for pH determination and analysis of both NH₃-N and TVFA, and the remaining vial was placed in the refrigerator at 4 °C for 2 h to stop fermentation. The remaining vials were filtered by gravity, using Whatman No. 4 filter paper, and the sediments were used for determining *in-vitro* crude protein degradability (IVCPD) in fresh residues. While the residues in the other bottles were directed at 105°C for 24 h to determine organic matter degradability (IVOMD) and neutral detergent fibre degradability (IVNDFD). For IVOMD measurement, the dry residues were burned at 550°C. Then, the following equations from Grings *et al.* (2005) were used to determine the production of microbial crude protein (MCP):

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

where OMD is organic matter digestibility.

Metabolizable energy (ME) was determined from *in-vitro* gas production, ignoring lipid content using Menke and Steingass (1988) equation:

$$\text{ME} = 2.20 + (0.136 \times \text{gas volume produced 24h}) + (0.0057 \times \text{CP})$$

where : CP is crude protein content.

In-vivo digestibility:

Sixteen adult Ossimi rams with similar mean body weight (BW) and similar variations (mean BW = 61.4±0.16 kg) were allotted randomly into four equal groups in a 4×4 Latin square experiment. The total digestibility was determined using the collection method by measuring daily forage intake for 24 days as an adaptation period (in an individual enclosure) and the following 7 days as a collection period (digestion cage). Rotating diets were randomly assigned to the animals, ensuring no animal obtained the same diet twice. Rams were fed tested silage *ad libitum* (4% BW based on DM) in two equal meals daily at 08:00 and 15:30 h, and they had unrestricted use of fresh water. During the adaptation period, refusal silage was weighed three times a week (on Monday, Wednesday, and Friday) to estimate each individual's daily DMI; however, during the collecting period, it was collected daily along with faeces. For each sheep, an aliquot of 10% of the weight of the faeces collected twice a day was pooled separately in the morning and evening and kept in the freezer at -20°C. Representative samples of feed, leftover feeds, and faeces were collected at the end of the collection period, oven-dried at 55°C for at least 72 hr, ground to pass through a 1 mm screen, and then stored until analyses. Subsamples were kept fresh for protein analysis. The actual silage consumed (FI) was calculated from the difference between the feed supplied and the feed rejected. Relative palatability (RP) indices were calculated as described by Abo-Donia *et al.* (2022):

$$\text{RP} = (\text{a component in FO} \times \text{mass FO}) - (\text{a component in RF} \times \text{mass RF}) \text{ for tested ERS}$$

where FO is the quantity of feed offered; RF is the quantity of feed residues (RF) and ensiled rice straw (ERS).

Apparent digestibility was estimated as the amount of nutrient intake not retrieval in faeces. The calculating TDN (Lofgreen, 1953) is as follows:

$$\text{TDN, (\%)} = (\text{DOM, \%}) + [1.25 \times (\text{digestible EE, \%})]$$

Ruminal fluid collection:

At the end of the digestibility trial, rumen liquor (RL) samples were taken via a stomach tube on two separate days from each adult male sheep before the morning feed. The first 10-mL sample was discarded to minimize false elevation of ruminal pH while the measurement began within 1 min of collection. Each sample was split into two sections; the first was filtered through four layers of cheesecloth, and the rumen pH, NH₃-N, total volatile fatty acid (TVFA), and VFA profiles were all determined. The second portion was immediately filtered through one layer of gauze cloth, fixed, and stained with four times as much methyl-green formalin saline solution (100 ml formaldehyde 35%, 900 ml distilled water, methyl-green 0.6 g, and sodium chloride 0.8 g), and then stored in a dark area until examination.

Blood collection:

The blood samples were collected from the jugular vein of sheep from each group (three per group) on two consecutive days after 4 hr of feeding at the end of the experimental period, then divided into two portions. The first portion of whole blood with anticoagulant that is immediately collected was used for estimating red blood cells (RBCs, $\times 10^6/\text{mm}^3$), white blood cells (WBCs, $\times 10^3/\text{mm}^3$), hematocrit value (HV, %), and haemoglobin (g/dl) concentration. The second portion of blood samples was centrifuged at 600 x g for 20 minutes to obtain blood plasma and stored at -20°C until assay of blood components.

Analytical procedures:

The sensory analysis of ERS (colour, smell, and texture) was inspected and subjectively judged by a panel involving five personnel before commencing the actual evaluation, independently according to a description by the method of Demirel *et al.* (2006). A fresh sample (25 g) of each CS, RSPL, RSPM, and RSPH was taken after 45 days, homogenized in a blender with 100 ml of sterilized distilled water, and shaken on a shaker at 250 rpm for 15 minutes. The content was filtered through four layers of cheesecloth and a qualitative filter paper (102, NewStar) and the filtrate was used for the determination of the pH using a portable pH meter (HANNA-pH meter, (model HI8424), Woonsocket, RI, USA). The lactic acid concentration was determined using the colorimetry method as described by James (1995). The concentration of ammonia-N was determined according to AOAC (2016) and total volatile fatty acids (TVFAs) according to Warner (1964) in filtered silage and RL. Partitioning factor (PF), as an index of efficiency in microbial protein synthesis, was calculated as the ratio of OM truly degraded (mg) to gas volume (mL) at 24 hr of incubation (Blümmel *et al.*, 1997). The Moller proportion of TVFAs in RL was determined by HPLC (column: Shodex RS Pak KC-811; Showa Denko K.K., Kawasaki, Japan; detector: DAD, 210 nm, SPD-20A; Shimadzu Co., Ltd, Kyoto, Japan; eluent: 3 mmol L⁻¹ HClO₄, 1.0 mL min⁻¹; temperature: 50°C). The individual VFAs were identified based on retention time comparisons with commercially available standards of acetic and propionic at $\geq 99\%$ purity (Sigma-Aldrich, St. Louis, MO, USA).

One drop of RL was poured on a hemocytometer slide, covered with a cover slip, and examined under a light microscope for protozoa count according to the description published by Dehority (1993). The following formula was used to determine the number of rumen protozoa present in 1 ml of RL:

$$\text{Number of protozoa/1 ml RL} = N \times 5 \times 10 \times 4$$

Where: N = Number of protozoa in one large corner square of white blood cells.

The total bacteria number for RL was determined by the anaerobic method of Bryant (1972) using the anaerobic diluents illustrated by Mann (1968).

Haematology blood parameters including the count of red blood cells (RBCs), white blood cells (WBCs), packed cell volume (PCV) and hemoglobin (Hb) were counted according to Hepler (1966). Blood's biochemical characteristics, including its total protein, albumin, glucose, creatinine, blood urea nitrogen (BUN), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) activity, were measured using kits that are readily accessible (Bio Mérieux SA, F-69280 Marcy l'Etoile, France) and carried out in accordance with the manufacturer's instructions. The concentration of globulin was calculated by subtraction of albumin from the corresponding total protein value.

Both mould and LAB of the experimental silages were estimated as expressed by Ranjit and Kung (2000), exactly 1 g of the silage was combined with 9 ml of sterile distilled water on the day of opening the silage, then serial dilution was carried out within 10⁻⁶ to 10⁻⁸. The dilutions were then plated on the subsequent media: de-Man-Rogosa-Sharpe agar (MRS) to detect LAB at 37°C for 2 days anaerobic, while Potato Dextrose Agar (PDA) to detect Mould at 25°C for 3 days and numbers of colony-forming (cfu) were expressed in log cfu/g. Composite tested silages, and faeces samples of sheep from each group were pooled and dried at 60°C for 72 hr. until a constant weight was achieved. Dried samples were ground to pass through a 40-mesh screen to analyze DM according to AOAC (2016). Dry matter recovery (DMR) of the tested silages was calculated according to Leão *et al.* (2017) using the following equation:

$$\text{DMR} = [(ms_0 \times dm_0) / (mse \times dm_{45})] \times 100$$

where:

DMR = dry matter recovery (%); ms₀ = silage mass at silo opening (kg); dm₀ = dry matter at silo opening (%/100); mse = silage mass at ensiling (kg); dm₄₅ = dry matter at ensiling (%/100).

The crude protein (CP) was determined in both fresh samples of silage and feces, to ensure the nitrogen does not volatilize with heat at drying. The Kjeldahl (Kjeltec 8200; FOSS, Höganäs, Sweden) measured total nitrogen (TN), and the CP was calculated as TN×6.25. Ash was incinerated in a muffle furnace at 550°C for 4 hr. to obtain a consistent weight. Ether extract in feed and faeces were determined by Soxhlet extraction (Soxtherm®) according to AOAC (2016). The NDF was assayed with the addition of a heat-stable amylase but without sodium sulfate and ADF, procedures were performed as a description by Van Soest *et al.* (1991) with a fiber analysis device (ANKOM Technology, Macedon, NY, USA). The water-soluble carbohydrates (WSC) consistency colorimetric determined by the phenol sulfuric acid method (Dubois *et al.*, 1956). Total soluble carbohydrates (TCH) and non-fiber carbohydrates (NFC) were calculated by difference according to Sniffen *et al.* (1992) as the following equation::

$$\text{TCH} = 100 - (\text{CP}\% + \text{EE}\% + \text{ash}\%)$$

$$\text{Non-fiber carbohydrates (NFC)} = 100 - (\text{aNDFom} + \text{CP} + \text{EE} + \text{ash})$$

Nutrient composition (% of DM) of ingredients, and experimental silages presented in Table (2).

Statistical analysis:

Four Latin squares were simultaneously used for a replicated design for statistical analysis of body weight, feed intake, digestibility, rumen fermentation, and blood parameters. Averages for each period and treatment combination were analysed (Duncan, 1955) to determine the fixed effects of a square, period (P), silage (S), and their interaction (S×P), and the random effects within a square using the mixed model procedures of SAS (2009). The model used for the data was:

$$Y_{ijkl} = \mu + B_i + P_j + S_k(B)_i + D_l + \epsilon_{ijkl}$$

where:

Y = dependent variable, μ = population mean, P_i = effect of period i, $S_k(B)_i$ = random effect of silage k within block i, D_l = fixed effect of silage l, ϵ_{ijkl} = residual error, normally and independently distributed (0, σ^2).

All terms were evaluated using the residual mean square error and differences were considered significant at $p \leq 0.05$.

Fermentation characteristics, microbiology, degradability (*IVOMD*, *IVNDFD* and *IVCPD*), and, *in-vitro* evaluation of experimental silage (one-way analysis)

$$Y_{ij} = \mu + t_i + e_{ij}$$

where: Y_{ij} = dependent variable, μ = mean of treatments, T_i = treatment effect; i, and e_{ij} = standard error; ij.

Kinetics of *in-vitro* gas production, Fermentation *in-vitro* gas production, (two-way analysis)

$$Y_{ijk} = \mu + t_j + \beta_j + (t\beta)_{ij} + e_{ijk}$$

where: Y_{ij} = dependent variable, μ = mean of treatments, T_i = treatment effect; i, β_j = time; j, $(t\beta)_{ij}$ = interaction; ij and e_{ijk} = standard error; ijk.

RESULTS AND DISCUSSION

Fermentation quality of experimental silages:

The results of Table (1) indicate the quality of the normal physical properties of (colour, odour, and texture) the RS ensiled with PPP compared to the CS. The different supplemented levels of PPP had a comparable effect on the quality of the silage produced in terms of texture when compared to the control

CS. In spite of the colour forming from yellowish in ERS to the olive green of CS, the incorporated levels of PPP into ERS caused more greenishness with the medium or high levels compared to the low level. El-Sheikh *et al.* (2020) asserted that the colour of the silage depends on the raw materials used, and that a close colour match to the original colour of the grass was considered an indication of acceptable quality silage. Additionally, it smelt slightly fruity for co-ensiled RS with PPP as compared to the control CS's acidic aroma. The smell of the experimental silages is considered a sign of well-made silage. As a result, the silage's smell and texture in the current experiment confirmed Grant and Ferraretto's (2018) hypotheses.

The water-soluble carbohydrate (WSC) values (%) increased significantly ($P < 0.05$) with the high level of PPP incorporation with RS, where RSPH has the highest value and the RSPL has the lowest value.

Table (1): Fermentation quality of the experimental silages.

Item	Experimental Silage				±SEM
	CS	RSPL	RSPM	RSPH	
Physical characteristics					
Texture	Firm, slightly lumpy	Firm, slightly lumpy	Firm, slightly lumpy	Firm, slightly lumpy	----
Color	Olive green	Yellowish-olive	Yellowish green	Yellowish green	----
Smell	Acid	Mild fruity	Mild fruity	Mild fruity	----
Fermentation characteristics					
WSC (%)	1.55 ^b	0.92 ^d	1.40 ^c	1.93 ^a	±0.038
pH	4.04 ^c	4.35 ^a	4.18 ^b	4.00 ^c	±0.039
Lactic acid (%DM)	4.21 ^a	3.88 ^b	3.97 ^b	4.10 ^a	±0.040
NH ₃ -N (% DM)	0.50 ^c	0.71 ^a	0.61 ^b	0.57 ^b	±0.016
VFA's (mmol/L)	74.33 ^a	70.74 ^c	73.28 ^b	74.11 ^{ab}	±0.303
Microbiology, (log¹⁰ cfu /g DM)					
LAB	4.03 ^a	2.05 ^c	3.06 ^b	4.20 ^a	±0.130
Molds	ND	ND	ND	ND	----

a, b, and c Mean within rows mean bearing different superscripts differ significantly at $P \leq 0.05$.

CS, corn stalk silage. RSPL, rice straw with 100 kg prickly pear peels-low level. RSPM, rice straw with 150 kg prickly pear peels-medium level and RSPH, rice straw with 200 kg prickly pear peels-high level. WSC, water-soluble carbohydrate. NH₃-N, ammonia nitrogen. VFA's, volatile fatty acids. cfu, logarithm colony-forming unit log. LAB, lactic acid bacteria. ND, not detected. SEM, standard error of means.

The result is consistent with that of Maciel *et al.* (2019) and is notable in that the higher soluble carbohydrate in PPP facilitated better LAB fermentation than suggested by the smell of the silage. Due to the low WSC content of the RS used in the current investigation, a rich carbohydrate source was used to help achieve a fermentation that was acceptable. The findings presented here are in line with those stated by Abo-Donia *et al.* (2022), who claim that good silage conditions promote the quick growth of LAB and prevent mould from penetrating the silage at 45 days.

Although rise amounts of PPP with ensiling RS led to a significant ($P < 0.05$) decrease in pH, the pH of CS and RSPH did not differ significantly, while for RSPL and RSPM the pH values were significantly higher than CS. The same trend was observed with NH₃-N, except for RSPH, which was significantly higher than that of CS. To achieve good quality and well-preserved silage, Abo-Donia *et al.* (2022) recommend pH levels above 3.5 to less than 5.0. As the concentration of WSC was increased, the pH was declined in the opposite direction. Mokoboki *et al.* (2016) found that the pH values in cactus cladodes silage was decreased with increasing molasses inclusion percentages. Because the NH₃-N levels in the current study were less than the 10% suggested by Mokoboki *et al.* (2016), there was no excessive protein breakdown.

Santos *et al.* (2020) documented that increasing the amount of the carbohydrate supply boosted the percentage of WSC, which was reflected in the pH value, the concentration of lactic acid, and the LAB count. According to El-Sheikh *et al.* (2020), RS includes low WSC content, while having a high

buffering capacity, and low populations of lactic acid bacteria (LAB), making it difficult to produce high-quality silage with just RS. The lactic acid and VFA's values were significantly ($P < 0.05$) lower with RSPL and RSPM comparable to CS, while no significant difference found between CS and RSPH. In spite of the count of LAB significantly ($P < 0.05$) increased with a raised amount of PPP incorporation with RS, the counts of LAB in RSPH were not statistically different from the CS. Data in the current study indicated the carbohydrates in PPP resulted in satisfactory fermentation when co-ensiled with RS. The silages examined had no evidence of mould. The carbohydrates introduced by PPP supplied enough fermentation substrate when co-ensiled with RS, especially with higher PPP levels, which accelerated the activity of LAB and accumulation of lactic acid and thus pH decline. This suggestion agreed with Morshedy *et al.* (2020) who reported that easily soluble/fermentable carbohydrates and the phenological stage of PPP improve the quality fermentation of silage. Moreover, Grant and Ferraretto (2018) warned the ensiling process is susceptible to fungal contamination in tropical areas with high temperatures, high humidity, and abundant oxygen.

Nutrient composition (% of DM) of the ingredients and experimental silages:

The data in Table (2) show that the PPP contents of the moisture, CP, NFC, and TCH were higher than those of RS. Those findings are consistent with findings from other studies (Salem *et al.*, 2004 and El-Neney *et al.*, 2019) which found the cactus to contain substantial quantities of moisture, while the content of NDF and ADF was lower.

The DM values of the experimental silages did not differ significantly ($P < 0.05$), which is in agreement with El-Sheikh *et al.* (2020), who recommended DM values between 35% and 40% for high-quality silages, whereas all silages showed values in the excellent range. Additionally, Gusha *et al.* (2015) investigated the composition and acceptability of a mixture of cactus silage and legume hay fed to animals during the scarcity period, and recorded that the silages demonstrated a reasonable fermentation pattern, with DM levels ranging from 37% to 43%.

When PPP was incorporated, ERS had a greater ash content, due to the higher level of inclusion. However, CS silage ash was significantly ($P < 0.05$) higher than ERS, which contained different levels of PPP. Higher mineral levels are responsible for the increased values of ash in ERS with increased PPP and may be advantageous when using low-quality roughages that are mineral-deficient. These findings have also been presented elsewhere by Gusha *et al.* (2015), El-Neney *et al.* (2019), and Inácio *et al.* (2020).

An increased PPP level included with RS resulted in a significant ($P < 0.05$) gradual improvement in the contents of both CP and EE, especially with the high level that did not differ significantly from CS. Those results are comparable with that investigated by El-Samahy *et al.* (2006) for CP, EE, and ash % content of the PPP. The high content of CP % (5.85) of PPP, shown in Table (2), is reflected by the CP % content of ERS with PPP inclusion. This result is comparable and in good agreement with the findings presented by El-Neney *et al.* (2019), Maciel *et al.* (2019), and Todaro *et al.* (2020).

Due to the presence of seeds with a high percentage of oils (up to 8.54%), according to Todaro *et al.* (2020), the PPP was more thoroughly incorporated into the RSPH silage than it was into the CS silage, which enhanced the EE contents. The chemical composition of the PPP content is as follows, according to Todaro *et al.* (2020): moisture 75.8%, protein 4.56%, fat 3.66%, fibre 7.72%, and ash 8.66%.

With the higher PPP incorporation level, the contents of NDF, ADF, and TCH declined significantly ($P < 0.05$) in ERS except TCH, these contents were also significantly ($P < 0.05$) lower with RSPH compared to CS. The content of NDF and ADF is an important indicator for forage quality regulators because they indicate the forage that an animal can consume. Due to composite silages being influenced by the nutrient level of each component, NDF, ADF, and TCH all decreased linearly as PPP inclusion increased (Table 2).

The results of the statistical analysis demonstrate that the incorporation of PPP into ERS increases ($P < 0.05$) significantly in DMR. In addition, there were significant ($P < 0.05$) increases in the DMR values for ERS inclusion at a high level of PPP compared to low and medium levels. Furthermore, there is a higher rate of sugar fermentation throughout the fermentation period, and this finding is consistent with that of Cüreğ and Özen (2004) and Santos *et al.* (2020). The difference in the results of the nutritional contents according to chemical analysis of ERS can be explained that the process of combining rice straw and PPP resulting in the dilution of some components while the concentration of others occurred. These observations are consistent with those made by Maciel *et al.* (2019) and Todaro *et al.* (2020).

Table (2): Nutrient composition (% of DM) of the ingredients, and experimental silages.

Item	Ingredients (%)			Experimental silage (%)			±SEM	P-value
	Cactus peel	Rice straw	CS	Ensiled rice straw				
				RSPL	RSPM	RSPH		
DM	29.54	90.13	40.01	40.03	40.04	40.00	0.021	0.4100
CP	5.85	3.58	8.02 ^a	7.34 ^c	7.71 ^b	7.98 ^a	0.066	<.0001
EE	2.89	0.89	0.98 ^b	0.60 ^d	0.82 ^c	1.33 ^a	0.026	<.0001
Ash	8.50	10.64	13.07 ^a	12.09 ^d	12.37 ^c	12.73 ^b	0.059	<.0001
NDF	39.49	70.13	61.12 ^d	67.73 ^a	63.53 ^b	61.77 ^c	0.132	<.0001
ADF	20.98	51.75	43.20 ^d	47.87 ^a	44.90 ^b	43.66 ^c	0.092	<.0001
NFC	43.3	8.90	16.80 ^a	12.25 ^d	15.58 ^c	16.20 ^b	0.098	<.0001
TCH	82.76	79.03	77.93 ^c	79.98 ^a	79.11 ^b	77.97 ^c	0.092	<.0001
DMR	----	----	91.08 ^c	92.06 ^b	92.49 ^b	93.58 ^a	0.157	<.0001

a, b, and c Mean within rows mean bearing different superscripts differ significantly at $P \leq 0.05$.

CS, corn stalk silage. RSPL, rice straw with 100 kg prickly pear peels-low level. RSPM, rice straw with 150 kg prickly pear peels-medium level and RSPH, rice straw with 200 kg prickly pear peels-high level. NDF, neutral detergent fiber. ADF, acid detergent fiber. NFC, Non-fiber Carbohydrates. TCH, total carbohydrates and DMR, dry matter recovery. SEM, standard error of mean. P-value, probability value.

***In-vitro* gas production kinetics and degradability of experimental silages:**

Table (3) displays the estimated values for the model of fractional rate of fermentation (c , h^{-1}), lag time (L , h), and asymptotic production of gas (A , mL/g DM incubated). Fig. (1) presents the gas accumulation curves (mL/g DM) for the different incubation times. The inclusion of PPP in ERS in the current study resulted in an increase in degradability with an increasing level of PPP incorporation.

Total gas generation is a measure of the degradation of easily fermentable materials (France *et al.*, 2000), which was not different across ERS with varied PPP levels for cumulative GP up to 72 hrs of incubation, with the exception of RSPL, which was dramatically reduced. When compared with CS, the higher OM content may be responsible for the increased gas emissions by ERS with the enhanced PPP included in the current study. In the current investigation, co-ensiled PPP and RS boosted GP during the final fermentation phase (GP72), especially with increasing levels and medium PPP incorporation, which may indicate a rise in the number of bacteria and, thus, the hydrolytic capacity of the ruminal fluid.

Similar to CS control, a medium or high level of PPP incorporation with RS had no effect on cumulative GP. Changes in *in-vitro* gas kinetics according to the impact of the ensiling process seems to be reported in many investigations (Gerlach *et al.*, 2018 and El-Sheikh *et al.*, 2020). Abo-Donia *et al.* (2018; 2022) showed that cumulative gas production *in-vitro* is related to the nutrient contents of the feed, in particular structural polysaccharides. The asymptotic gas production (A , mL/g DM incubated) values of the RSPL silage were significantly ($P < 0.05$) lower than all the other experimental silages, while there were not significant differences in the values of the fractional rate of fermentation (c , h^{-1}) and lag time (L , h) across the various silages. El-Sheikh *et al.* (2020) found a significant positive correlation between the amount of NDF in the feed and the rates of GP accumulation ($r = 0.80$) and *in-vitro* organic matter degradability ($r = 0.83$). Moreover, this assumption implies that rumen microorganisms took the same time to break down the CS control feeding substrate, resulting in the lag time (L) being convergent (Maciel *et al.*, 2019). The positive effect of fermenting an increased amount of DM for diet in a shorter period of time reflects on the lag time (L) among the experimental silages in the current study (Maciel *et al.*, 2019).

The values of pH were decreased with the increase of incorporated PPP in ERS significantly ($P < 0.05$) compared to CS, except RSPH did not differ significantly. Moreover, NH_3 concentration significantly ($P < 0.05$) decreased with the inclusion of PPP in ERS compared to CS. The results of *in-vitro* IVOMD, IVNDFD, and IVCPD show that the degradability values were significantly ($P < 0.05$) lower with levels of PPP 100 and 150 kg in ERS compared to RSPH and CS. Gerlach *et al.* (2018) hypothesised that the feeding of high-quality ensiled materials will improve the degradability of feed that has a high proportion of potentially degradable fractions. The N source provided by PPP for the microorganisms improved fiber degradation and elevated IVOMD, IVNDFD, and IVCPD values (Macêdo *et al.*, 2018).

Table (3): In-vitro gas production kinetics and degradability of the experimental silages.

Item	Experimental silages				±SEM	P-value
	CS	Ensiled rice straw				
		RSPL	RSPM	RSPH		
Kinetics of in-vitro gas production						
A (mL/g DM)	62.50 ^{ab}	60.75 ^c	62.38 ^{ab}	63.20 ^a	0.623	0.0913
c (ml/h)	0.0375	0.0374	0.0368	0.0379	0.001	0.9393
L (h)	0.460	0.482	0.459	0.293	0.074	0.2908
Fermentation in-vitro gas production						
pH	6.06 ^c	6.52 ^a	6.26 ^b	6.00 ^c	0.060	0.0002
NH ₃ -N (mg/dl)	9.95 ^c	14.20 ^a	12.28 ^b	11.35 ^c	0.322	<.0001
SCFA's (meq/dl)	9.91 ^a	9.43 ^c	9.77 ^b	9.88 ^{ab}	0.040	<.0001
In-vitro 48-h degradability, (%)						
IVOMD	56.46 ^a	50.86 ^b	51.93 ^b	56.79 ^a	0.518	<.0001
IVNDFD	51.70 ^a	45.72 ^c	48.97 ^b	52.03 ^a	0.393	<.0001
IVCPD	47.70 ^a	42.74 ^c	44.81 ^b	48.24 ^a	0.356	<.0001
In-vitro evaluation						
ME (Mcal/kg)	7.353	7.169	7.339	7.493	0.110	0.2769
MP	1.82 ^a	1.60 ^c	1.67 ^b	1.83 ^a	0.016	<.0001
PF	0.98	0.91	0.90	0.96	0.024	0.1063

^{a, b, and c} Mean within rows mean bearing different superscripts differ significantly at $P \leq 0.05$.

CS, corn stalk silage. RSPL, rice straw with 100 kg prickly pear peels-low level. RSPM, rice straw with 150 kg prickly pear peels-medium level and RSPH, rice straw with 200 kg prickly pear peels-high level.

NH₃-N, ammonia nitrogen. A, asymptotic gas production (mL/g DM incubated). C, fractional rate of fermentation (h⁻¹). L, lag time (h). ME, metabolizable energy. MP, microbial protein and PF, partitioning factor (mg DM digested/ML fermentation gas). IVOMD, in-vitro organic matter degradability. IVNDFD, in-vitro neutral detergent fibre degradability. IVCPD, in-vitro crude protein degradability. SEM, standard error of means. P-value, probability of value. SEM, standard error of mean. P-value, probability value.

The results in Tables (1), (2), and (3) indicate that more incorporation of PPP with RS decreases total fibre, fetches better quality silage with increased degradability, and helps in the proliferation of microorganisms in the rumen to break down the feed substrate and produce gas (DeSilva Brito *et al.*, 2020). In accordance with El-Sheikh *et al.* (2020), the main source of proteolysis in corn silage was bacterial activity that improved rumen degradability, and that findings for IVCPD in Table (3) are consistent with this conclusion. In regard to protein evaluation, the current study demonstrates that IVCPD, microbial protein (MP) and protein digestibility values were linearly ($P < 0.05$) improved with an increased level of PPP incorporation, these results are consistent with El-Neney *et al.*, (2019). The MP values are within the variation of 1.2 to 1.7 mg/dL, according to Inácio *et al.* (2020) and Gusha *et al.* (2015), where these values within this variation would indicate an adequate balance of degraded protein and energy fermented. For high roughage-fed ruminants, microbial cells are considered a principal source of protein (50–95% as non-ammonia nitrogen, NAN) flowing to the post-ruminal (Gusha *et al.*, 2015 and Inácio *et al.*, 2020). However, microbial mass supplies the majority of the amino acids (AA) that the host animal demands for tissue maintenance, growth, and production (El-Sheikh *et al.*, 2020). Nevertheless, there were no significant differences in MP values when incubating the ERS including a high level of PPP compared to the control CS. The variation in calculated values of the synthesis and synthesis efficiency of the MP (Table 3) with the diets containing PPP may be due to the carbohydrate content (Table 2), which was sufficient for providing the necessary energy for fiber fermentation and microbial synthesis. No significant differences were found in the values of ME (Mcal/kg) and partitioning factor (PF) among the different experimental silages.

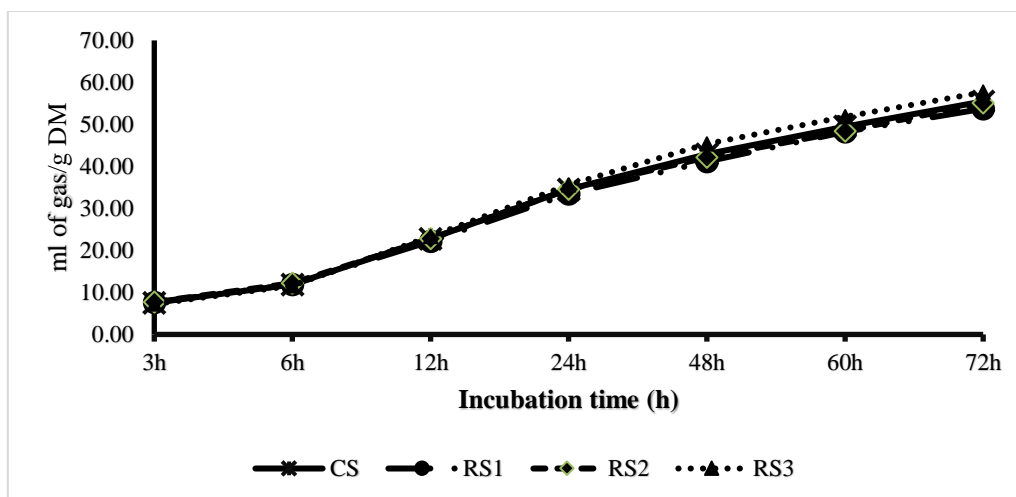


Fig. (1): Gas accumulation (mL/g DM) at the different incubation times

Feed intake, digestibility, and nutritive values of experimental silages:

The results of body weight, feed intake, digestibility, and nutritive values of the experimental silages are shown in Table 4. The consumption of ERS that included PPP significantly ($P < 0.05$) increased with the gradual increase in the level of inclusion. While the differences were significant between CS compared to RSPL and RSPM, no significant differences were seen between CS and RSPH. These results are consistent with the finding by DeOliveira *et al.* (2017). However, consumption of ERS combined with a higher-level PPP did not differ significantly from the control CS, which was in line with past studies that discovered that ensiling procedures did not reduce nutrients intake as a result of their fermentation features (El-Sheikh *et al.*, 2020). Feed consumption of ERS improved gradually with increasing PPP incorporation into ERS, however, it remained significantly ($P < 0.05$) lower compared to CS, excluding RSPH no significant differences were shown. This finding may be due to the relationship between lactic acid, ammonia, and silage odour which may be favorable for intake improvement as suggested by Gusha *et al.* (2015). Although the refusal of the ERS that included PPP decreased significantly ($P < 0.05$) with increasing in the level of inclusion, no significant difference was found between the refusal ERS that included a higher level of PPP compared to the control CS. The increased DM intake of ERS with the increased incorporation of PPP may have occurred for several reasons. First, plant cell contents affect DM intake, because the plant cell wall (also known as structural fibre) is a key factor in determining DM intake (Abo-Donia *et al.*, 2018). Second, as demonstrated in Table (2) and stated by De Oliveira *et al.* (2017), a higher fiber fermentation in ERS was likely caused by a process that reduced the toughness of the fiber properties. This action may have reduced rumen mean retention time (MRT) and rumen fill, thereby decreasing the inhibition of intake.

The palatability (%) of the experimental silages was going in the same direction as the feed consumption. Gradual improvement of palatability with increasing levels of PPP incorporation may be attributed to the fact that prickly pear exhibits high palatability (an important source of energy for ruminants) and accordingly is considered an ideal source of NFC (Salem *et al.* 2004). Morshedy *et al.* (2020) indicated that large quantities of PPP can be consumed voluntarily, this recommendation may explain the fact of the palatability of ERS included the highest level of PPP, which accomplishes not differ significantly from CS.

The nutrient digestibility of DM, OM, CP, NDF, and ADF were significantly ($P < 0.05$) increased with increasing PPP inclusion of ERS. These results in the current study indicate that the higher level of PPP incorporation in ERS leads to a decrease in the content of ADF and NDF, moreover, ADF and NDF in PPP are more digestible than ADF and NDF in RS, therefore, the elevated PPP level in ERS did not show significant differences in the digestion of ADF and NDF compared with CS. This observation agreed with Gusha *et al.* (2015) who recommended that higher ADF and lower N rate slowed nutrient degradation due to full rumen resulting in lower forage intake. The digestion coefficient of EE of ERS with PPP incorporation was significantly ($P < 0.05$) higher with increasing the level of PPP inclusion.

Though the EE digestibility of the control CS silage did not differ significantly with ERS containing a medium level of PPP, it was significantly ($P < 0.05$) lower than ERS included a higher level of PPP, and

significantly higher ($P < 0.05$) compared to ERS, which included a low level of PPP. The high coefficient of digestibility of the EE is due to the presence of a portion of prickly pear seeds that contains a high percentage of crude fat (8.54%), which also helps in providing energy for animals. In resemblance to the present results, which indicated a progressive improvement in the digestibility of nutrients for DM, OM, CP, NDF, and ADF, from ERS with increased inclusion of PPP. Morshedy *et al.*, (2020) demonstrated that the nutrients obtainable from the inclusion are beneficially employed by microorganisms in the rumen. Carbohydrate is necessary as an energy source for ruminal microbial protein synthesis (El-Sheikh *et al.*, 2020). Presumably, elevated NSC present in cactus plants indicates that increased incorporation of them with RS leads to an increase in the digestibility of nutrients, especially with sufficient nitrogen availability (El-Neney *et al.*, 2019).

The nutritional values of the experimental silages as shown in Table (4) showed that the values of TDN and DCP gradually improved ($P < 0.05$) significantly with the increasing inclusion of PPP in ERS. Although the ERS that included low and medium levels of PPP was significantly ($P < 0.05$) lower compared to CS, the higher level of incorporation showed no significant difference compared to CS. The lower contents of both NDF and ADF could increase the digestibility of the ensiling RS and dry matter intake, because there is a negative correlation between both NDF and ADF with digestibility and intake (Morshedy *et al.*, 2020).

Table (4): Body weight, feed intake, nutrients digestibility, and nutritive values of the experimental silages.

Item	CS	Experimental silages			±SEM	P-value		
		Ensiled rice straw				S	P	S*P
		RSPL	RSPM	RSPH				
Body weight (kg/h)	62.88	62.88	62.38	62.88	0.466	0.8337	1.0000	1.0000
Feed intake (Kg /day)								
Silage offered	1.572	1.572	1.559	1.572	0.012	0.8330	1.0000	1.0000
Silage refused	0.156 ^d	0.429 ^a	0.289 ^b	0.171 ^c	0.003	<.0001	0.4911	0.3380
Silage consumption	1.416 ^a	1.143 ^c	1.270 ^b	1.401 ^a	0.010	<.0001	0.9607	0.9897
Relative Palatability (%)	90.08 ^a	72.69 ^c	81.46 ^b	89.31 ^a	0.163	<.0001	0.2662	0.0904
Digestion coefficients (%)								
DM	63.90 ^a	53.17 ^c	60.66 ^b	63.82 ^a	0.108	<.0001	0.0126	0.0035
OM	66.12 ^a	57.30 ^c	62.24 ^b	65.95 ^a	0.100	<.0001	<.0001	0.0059
CP	67.37 ^a	55.29 ^c	61.77 ^b	67.25 ^a	0.109	<.0001	<.0001	0.0101
EE	70.74 ^b	53.67 ^c	66.71 ^b	71.47 ^a	0.220	<.0001	0.2355	0.0329
NDF	66.75 ^a	52.04 ^c	62.95 ^b	66.23 ^a	0.212	<.0001	0.0031	<.0001
ADF	61.03 ^a	46.92 ^c	58.18 ^b	60.96 ^a	0.145	<.0001	<.0001	<.0001
Nutritive values (%)								
TDN	58.32 ^a	50.85 ^c	55.06 ^b	58.64 ^a	0.087	<.0001	<.0001	0.0043
DCP	5.39 ^a	4.04 ^c	4.78 ^b	5.37 ^a	0.009	<.0001	<.0001	0.0097
Nitrogen balance (g/h/d)								
N intake (g N/day)	18.12 ^a	13.36 ^c	15.73 ^b	17.91 ^a	0.120	<.0001	0.9552	0.9876
Faecal-N (g N/day)	12.21 ^a	7.39 ^c	9.72 ^b	12.05 ^a	0.086	<.0001	0.3228	0.9438
Urinary-N (g N/day)	5.61 ^b	5.80 ^a	5.78 ^a	5.49 ^b	0.045	<.0001	0.0035	0.0032
N retained (g N/day)	0.30 ^a	0.17 ^c	0.23 ^b	0.37 ^a	0.015	<.0001	<.0001	<.0001

^{a, b, and c} Mean within rows mean bearing different superscripts differ significantly at $P \leq 0.05$.

CS, corn stalk silage. RSPL, rice straw with 100 kg prickly pear peels-low level. RSPM, rice straw with 150 kg prickly pear peels-medium level and RSPH, rice straw with 200 kg prickly pear peels-high level. NDF, neutral detergent fiber. ADF, acid detergent fiber. SEM, standard error of means. S, silage. P, period. P-value, probability of value. TDN (%) = $DOM\% + 1.25 \times (DEE\%)$. DCP (%) = $CP\% \times (Dig. CP\%/100)$

The nutrition value of CS silage was significantly ($P < 0.05$) higher compared to ERS containing a low level of PPP, while it did significantly ($P < 0.05$) different compared to ERS containing a higher level of PPP, but it was significant ($P < 0.05$) differences when compared with ERS containing a medium level of PPP.

The improved digestibility of all nutrients in ERS that accompanied the increase in PPP inclusion can be argued to be due to the enrichment of minerals and amino acids (El-Neney *et al.*, 2019), and high

contents of malic acid, vitamin A, vitamin E, and vitamin C, flavonoids, and carotenoids (Macêdo *et al.*, 2018). On the other hand, the presence of phenolic components (Morshedy *et al.*, 2020), and compounds with antimicrobial effects (El-Samahy *et al.*, 2006 and El-Neney *et al.*, 2019), may be associated with enhancing the digestion of all nutrients. The results for N-intake, faecal-N, and N-retained indicate a significant ($P < 0.05$) increased with increasing in PPP inclusion in ERS. The high concentration of soluble carbohydrates in the PPP, an important source of VFA's supply, may facilitate its combination with N and consequently enhancement of microbial protein by the host animal according to a report by Morshedy *et al.* (2020). The results of N-intake, faecal-N, and N-retained were significantly ($P < 0.05$) high for both CS and RSPH (which included a high level of PPP) compared to RSPL (which contained a low of PPP). Urinary N values were significantly higher when fed on RSPL and RSPM compared to CS and RSPH. Noteworthy, the urinary N loss was high in groups fed ERS and could be from muscle protein turnover, some of this protein is caught and others lost in urine as endogenous urinary N losses, as suggested by Gusha *et al.* (2015).

There was a high ($P < 0.05$) faecal N loss with fed CS and RSPH diets, which would be attributed to the low degradation of feed in the rumen due to the high levels of polyphenolic compounds such as tannins, condensed tannins, phytate, and oxalate in cactus peels (Morshedy *et al.*, 2020), high ADF, and low N in rice straw (Abo-Donia *et al.*, 2022).

Characteristics of rumen fermentation:

The basic pattern of rumen fermentation in adult male sheep fed experimental silage is shown in Table (5). The pH values significantly ($P < 0.05$) decreased in the rumen of sheep fed on ERS containing PPP, and the decline was raised with an increase in the incorporate level. These observed values were within the ranges observed by Morshedy *et al.* (2020), which range from 6.24 to 6.80. In comparison to the other experimental groups, the control group that received CS had significantly ($P < 0.05$) lower pH levels. It is possible that a lower level of PPP in the ERS leads to an increase in mastication, which causes an elevated in the pH value of the rumen (Abo-Donia *et al.*, 2022). Additionally, relieved ERS pH with an increased level of PPP inclusion, particularly with increased consumption of ERS as shown in Table (4), may have contributed to the deficient rumen pH, which is consistent with previous reports (Gusha *et al.*, 2015). The values of ammonia-N concentration were significantly ($P < 0.05$) higher for the group fed on RSPL compared to the other groups, with no significant difference among them. Rumen parameters revealed that sheep fed a diet containing RSPM and RSPH lead to enhanced protein utilization, which was demonstrated by lower ruminal $\text{NH}_3\text{-N}$ concentration compared to those fed RSPL, this finding is a good agreement with that reported by Morshedy *et al.* (2020) In the same sense, the presence of tannins and polyphenols in PPP at reasonable levels probably improved the performance of the animals due to better utilization of protein intake (Gusha *et al.*, 2015). This occurs through binding proteins, consequently lowering their ruminal degradation and resulting in a high flow of amino acids to the small intestine (Macêdo *et al.*, 2018). The concentration values of VFA's and acetate increased ($P < 0.05$) significantly when sheep were fed ERS, especially with that the increase in the level of PPP incorporation. In spite of being significantly ($P < 0.05$) lower compared to the CS-fed group, but did not differ significantly from the RSPH-fed. Although the values of VFA's in the rumen were significantly ($P < 0.05$) lower when feeding on RSPL and RSPM compared to CS, it should be noted that increasing the level of PPP inclusion in the ERS led to an improvement in the fermentation of the sheep rumen and increased the total percentages of VFA's, acetate, and butyrate. These findings are consistent with those of Morshedy *et al.* (2020), who used prickly pear cactus peels in the sheep diet and found that total VFA and proportion concentrations were higher when sheep were fed *Opuntia ficus* along with dry forage legumes. Gusha *et al.* (2015) also domesticated that higher total VFA and proportion concentrations were observed when sheep were fed co-ensiling *Opuntia ficus*.

Furthermore, a decrease in the rumen concentration of $\text{NH}_3\text{-N}$ in the rumen of ERS-fed sheep with medium and high PPP levels correlates with higher rumen total VFA's, indicating an improved fermentation rate and higher microbial protein synthesis (Gusha *et al.*, 2015 and El-Sheikh *et al.*, 2020). The results of the bacteria and protozoa count in the rumen of sheep fed on CS were higher ($P < 0.05$) compared to other experimental groups fed on ERS with PPP inclusion. Nevertheless, the count of bacteria and protozoa for sheep rumen fed ERS containing a higher level of PPP was significantly ($P < 0.05$) higher compared to those fed ERS containing a medium or low level of PPP, except for the bacterial count of the group that fed RSPM. These results indicate that the inclusion of high levels of PPP in ERS could have a positive effect on microbial communities. In spite of the fact that tannins can have diverse effects on protozoa count in the rumen, they generally depress ruminal protozoa count (El-Sheikh *et al.*, 2020). The lack of an antiprotozoal impact with ERS-included PPP is in line with the findings of Cieslak *et al.* (2012), who showed that feeding PPP did not reduce the amount of bacteria or

protozoans in sheep's rumen. Although the mechanism of action of tannins on protozoa is unclear, according to Cieslak *et al.* (2012), it may be comparable to that observed on bacteria.

Table (5): Rumen fermentation parameters of adult male sheep fed the experimental silages.

Item	Experimental Diets				±SEM	P-value		
	CS	Ensilaged rice straw				S	P	S*P
		RSPL	RSPM	RSPH				
pH	5.84 ^d	6.02 ^a	6.10 ^b	5.94 ^c	0.016	<.0001	0.6422	0.0288
NH ₃ -N (mg/L)	163.6 ^b	200.3 ^a	168.2 ^b	166.9 ^b	1.889	<.0001	0.7054	0.9834
TVFAs (meq/100 mL)	11.84 ^a	10.65 ^c	11.67 ^b	11.72 ^a	0.028	<.0001	0.5636	0.1149
Acetate (Mol/100 mol)	60.72 ^a	53.43 ^c	59.23 ^b	60.35 ^a	0.266	<.0001	0.2513	0.4845
Propionate (Mol/100 mol)	21.03 ^a	18.96 ^b	20.99 ^a	21.07 ^a	0.074	<.0001	0.4987	0.0146
Bacteria (10 ⁶)	6.47 ^a	5.78 ^c	6.26 ^b	6.31 ^b	0.042	<.0001	0.5558	0.8832
Protozoa (10 ³)	3.90 ^a	3.41 ^d	3.69 ^c	3.80 ^b	0.029	<.0001	0.9505	0.5017

^{a, b, and c} Mean within rows mean bearing different superscripts differ significantly at $P \leq 0.05$.

CS, corn stalk silage. RSPL, rice straw with 100 kg prickly pear peels-low level. RSPM, rice straw with 150 kg prickly pear peels-medium level and RSPH, rice straw with 200 kg prickly pear peels-high level. NH₃-N, ammonia nitrogen. TVFA's, total volatile fatty acids. SEM, standard error of mean. S, silage. P, period. P-value, probability of value.

Biochemical and hematological parameters:

Results in Table (6) showed that the sheep's blood concentrations of total protein, albumin, and glucose. Although these values increased ($p < 0.05$) significantly with higher PPP levels when fed to ERS, they decreased significantly with feeding to RSPL and RSPM compared to CS, except that values when feeding to RSPH did not show a significant difference. According to Morshedy *et al.* (2020), blood biochemistry measures including TP, AL, and GL are very important as reliable indicators of nutritional status. No significant differences were found among the experimental groups for the concentration of globulin, ALT, or AST in sheep's blood. The matching of total protein, albumin, globulin, and glucose values were observed with El-Neney *et al.* (2019), and AST, ALT, creatinine, and urea with Morshedy *et al.* (2020) when utilizing PPP in animal diets, and the values were within the standard range for biochemical and haematological parameters of sheep. In the same context, the current findings are in harmony with those of El-Neney *et al.* (2019), who found that AST and ALT activities were not affected by dietary treatments supplemented with PPP. The glucose concentration in the blood of the experimental groups showed the same trend for total protein and albumin. The trends in the urea concentration tend to be opposite to glucose when sheep fed RS silage with PPP and the urea value is often used as a criterion for the amino acid metabolic grade of ruminants (Abo-Donia *et al.* 2022). The elevated TP with the incorporation of a higher level of PPP into the ERS could be attributed due to the sufficient digestibility of the CP and also because carbohydrates increased protein utilization as a result of improved rumen fermentation.

The urea and creatinine concentrations in sheep blood that fed ERS were decreased significantly ($P < 0.05$) with increasing in PPP level incorporation. However, the control group had a significantly ($P < 0.05$) lower urea concentration compared with the groups fed RSPL and RSPM, but it did not differ significantly compared to the group fed RSPH. The values of serum creatinine concentration (1.19 -1.27 mg/dL) were within the values (1.1 -1.9 mg/dL) reported by Abo-Donia *et al.* (2018). The results of blood urea and creatinine concentrations clarified that feeding ERS including PPP did not affect kidney function (as shown in Table 6), and it was in harmony with the findings of Morshedy *et al.* (2020). Regarding the haematological parameters, the values of haemoglobin (g/dl), RBCs ($\times 10^6/\text{mm}^3$), WBCs ($\times 10^3/\text{mm}^3$), and PCV (%) had the same tendency in sheep blood. The haematological parameters showed a significant ($P < 0.05$) increase in the blood of the groups fed ERS, especially with an increasing level of PPP incorporation. A useful indicator of feed toxicity is the mean corpuscular haemoglobin content, particularly when the feed component affects both the blood and the health of farm animals (Morshedy *et al.*, 2020). The values of hemological components in the current study fell within the values reported for healthy sheep by (El-Neney *et al.* 2019). The control group fed CS showed significantly ($P < 0.05$) higher concentrations of haematological parameters compared with that fed RSPL and RSPM, it did not significantly differ from that fed by RSPH. Morshedy *et al.* (2020) noted that the presence of alkaloids and tannins in PPP may

overshadow on reduction of WBC's in the blood of sheep. The results of haemoglobin, RBCs, WBCs, and PCV in the current study were in consensus with those reported by El-Neney *et al.* (2019), who found that these parameters were significantly increased in sheep blood with increased levels of prickly pear peel in the ration.

Table (6): Blood biochemical and hematological parameters of sheep fed the experimental silages.

Item	Experimental Diets				±SEM	P-value		
	CS	Ensiled rice straw				S	P	S*P
		RSPL	RSPM	RSPH				
Biochemical parameters								
Total protein	6.14 ^a	6.00 ^c	6.05 ^b	6.12 ^a	0.011	<.0001	0.8026	0.5345
Albumin	3.17 ^a	2.99 ^c	3.04 ^b	3.15 ^a	0.030	0.0002	0.9399	0.0468
Globulin	2.97	3.01	3.00	2.97	0.027	0.5635	0.8339	0.0468
Glucose	58.86 ^a	53.18 ^c	56.18 ^b	58.13 ^a	0.137	<.0001	0.5254	0.2500
AST	36.38	36.47	36.56	37.02	0.318	0.4994	0.6284	0.8570
ALT	16.06	16.10	16.16	16.59	0.145	0.5008	0.6927	0.0003
Creatinine	0.88 ^a	0.87 ^a	0.86 ^b	0.86 ^b	0.001	<.0001	0.6149	0.0879
Urea	14.10 ^c	15.39 ^a	14.83 ^b	14.36 ^c	0.093	<.0001	0.7412	0.5994
Hematological parameters								
Hemoglobin (g/dl)	128.4 ^a	124.8 ^c	126.3 ^b	128.2 ^a	0.005	<.0001	0.9082	0.9864
RBCs (x10 ⁶ /mm ³)	10.4 ^a	9.7 ^c	10.0 ^b	10.7 ^a	0.034	<.0001	0.1716	0.2302
WBCs (x10 ³ /mm ³)	10.2 ^a	9.73 ^c	9.95 ^b	10.3 ^a	0.001	<.0001	<.0001	<.0001
PCV (%)	39.5 ^a	37.0 ^c	38.6 ^b	39.6 ^a	0.004	<.0001	<.0001	<.0001

^{a, b, and c} Mean within rows mean bearing different superscripts differ significantly at $P \leq 0.05$.

CS, corn stalk silage. RSPL, rice straw with 100 kg prickly pear peels-low level. RSPM, rice straw with 150 kg prickly pear peels-medium level and RSPH, rice straw with 200 kg prickly pear peels-high level.

AST, aspartate-aminotransferase. ALT, Alanine-aminotransferase. RBCs, red blood cells. WBCs, White blood cells. PCV, packed cell volume. SEM, standard error of mean. S, silage. P, period.. P-value, probability of value.

CONCLUSION

The incorporation of PPP as a source of energy with RS mass at a level of 100 to 200 kg/ton was able to accelerate the early phase of the acidification process and limit the existence of coliforms and Enterobacteriaceae after a 45-day storage period. terms of the digestion coefficients of the nutritional components, the ensiled rice straw with the incorporation of a higher level of PPP showed an improvement in the digestion of the nutritional components and was a good source of energy and protein for the animals. At the same time, there were no indications of health problems in the animals that were fed ensiled rice straw. Further research is necessary to enhance the technique for maintaining PPP mass throughout storage and to establish the production responses in ruminant species.

CONFLICT OF INTEREST:

We assure that the material covered in the manuscript is not in conflict with any financial organisations.

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تأثير التغذية على سيلاج قش الأرز المرطب مع قشور فاكهة التين الشوكي على قابلية التحلل والهضم والقيمة الغذائية للاغنام

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هذه الدراسة تهدف الى تقييم استخدام سيلاج الارز (ERS) المرطب بادخال ثلاث مستويات من قشور فاكهة التين الشوكي (PPP): وزن: 100 ، 150 ، و 200 كجم لكل طن من قش الأرز (RS) والمقارنة بمجموعة بسيلاج الذرة (CS) ، مع اضافة 5 كجم من اليوريا و 25 كجم من المولاس الى جميع المعاملات ومعامله المقارنة في تجربة باستخدام المربع اللاتيني 4 × 4 ، تم تقسيم 16 كيش اوسيمي (61.4 ± 0.16 كجم) بشكل عشوائي الى أربع مجموعات متساوية. أظهرت النتائج حدوث تحسن في قيم كلا من الاحماض الدهنية الطيارة وعدد بكتريا حمض اللاكتيك (LAB) في مجموعه سيلاج الارز المضاف الية قشور التين الشوكي، بينما انخفضت معنويا (P < 0.05) قيم الرقم الهيدروجيني (pH) والامونيا (NH₃-N) ولم يتم الكشف عن اى اعفان في جميع انواع السيلاج المختبرة والمقارنة. في حين انخفضت قيم كلا من NDF و ADF و الكربوهيدرات في مجموعة ERS مع زيادة مستوى PPP في السيلاج كما ارتفعت قيم الرماد. في حين ان قيم استعادة المادة الجافة (Dry matter recovery) كانت اعلى مع ERS مقارنة بمجموعة التحكم CS. لم يوجد فروق في انتاج الغاز التراكمى حتى 72 ساعة من التحضين نتيجة زيادة مستويات PPP. اظهرت النتائج ايضا ارتباط زيادة قيم كلا من IVOMD و IVNDFD و IVCPD بزيادة الماكول من ERS. زادت قابلية هضم العناصر الغذائية معنويا (P < 0.05) في صورة DM و OM و CP و NDF و ADF مع زيادة PPP في ERS كما زاد ايضا كلا من TDN و DCP. كما أدى زيادة مستوى PPP في سيلاج ERS الى الانخفاض المعنوى (P < 0.05) في النيتروجين المحتجز. بينما زاد معنويا (P < 0.05) كلا من الامونيا (NH₃-N) والاحماض الدهنية الطيارة (TVFAs) والاسيتات والعدد البكتيرى والبروتوزوا في كرش الحيوانات التي تغذت على ERS بزيادة مستوى قشور التين الشوكي، في حين لم تظهر اى فروق ذات دلالة معنوية في دم الاغنام بالنسبة لكلا من globulin و ALT و AST بينما زاد الجلوكوز معنويا عند التغذية على ERS ومع زيادة مستوى PPP ، في حين انخفض تركيز كلا من اليوريا والكرياتينين. كما اتخذت نفس الاتجاه قيم كلا من hemoglobin و erythrocytes و white blood cells و PCV. وبالتالي يمكن التوصية باستخدام السيلاج المتكون من قش الارز مع قشور فاكهة التين الشوكي حيث ادى الى تحسن خصائص التخمرات وبالتالي يوصى باستخدامه كمصدر علفي للاغنام خاصة عند مستوى 200 كجم لكل طن سيلاج.