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REGULAR ARTICLES

# Effect of urea-treated rice straw, mixed with faba bean straw, on nutrient digestibility, blood metabolites and performance of growing lambs

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**Abstract**

The present study aimed to use poor quality roughages, such as rice and faba bean straw, treated with or without urea, and their impacts on digestibility, rumen fermentation, some blood parameters, and growth performance of lambs. Twenty crossbred male lambs ($^{1}/_{4}$ Finland ×¾ Ossimi, 25±1.13kg live body weight) were chosen and divided into four groups. All lambs were fed rations of concentrated feed mixture at 2% of live weight with the following roughages *ad libitum*: URS (control group, untreated rice straw), TRS (urea-treated rice straw), FBS (faba bean straw), and TRS+FBS (mixture of TRS and FBS, 1:1). Nutrient digestibility and feeding values improved ($P<0.05$) with TRS+FBS lambs *versus* FBS, TRS and URS lambs. The highest numerical values of ruminal total volatile fatty acid (VFA) concentration in TRS lambs were recorded 23.9 ml.eq/dl followed by TRS+FBS, URS and FBS. Regarding to the ruminal parameters, there were no differences ($P>0.05$) among evaluated groups except for $NH_3$-N, the highest concentration ($P<0.05$) was recorded in TRS lambs at 3 h post-feeding. Lambs of TRS, FBS and TRS+FBS showed faster growth ($P<0.05$) than those of the control (*i.e.,* URS). Intakes of dry matter, total digestible nutrients, and digestible crude protein were numerically increased for TRS, FBS, and TRS+FBS. Feed conversion, as kg dry matter/kg gain, was improved for TRS, FBS, and TRS+FBS lambs *versus* URS. Daily gain of lambs increased ($P<0.05$) with lambs of TRS, FBS, and TRS+FBS but URS lambs showed a decrease ($P<0.05$) in daily gain. Feed conversion as kg dry matter intake/kg gain was improved ($P<0.05$) by feeding on TRS, FBS and TRS+FBS rations *versus* URS. The TRS+FBS lambs tended to have the highest economic efficiency *versus* URS, TRS and FBS lambs. It was concluded that urea-treated rice straw could be used as sole roughage or mixed with faba bean straw (1:1) in growing lambs' ration to improve their performance and economic efficiency without adversely affecting their health.

The present study aimed to use poor quality roughages, such as rice and faba bean straw, treated with or without urea, and their impacts on digestibility, rumen fermentation, some blood parameters, and growth performance of lambs. Twenty crossbred male lambs ($^{1}/_{4}$ Finland ×¾ Ossimi, 25±1.13kg live body weight) were chosen and divided into four groups. All lambs were fed rations of concentrated feed mixture at 2% of live weight with the following roughages *ad libitum*: URS (control group, untreated rice straw), TRS (urea-treated rice straw), FBS (faba bean straw), and TRS+FBS (mixture of TRS and FBS, 1:1). Nutrient digestibility and feeding values improved ($P<0.05$) with TRS+FBS lambs *versus* FBS, TRS and URS lambs. The highest numerical values of ruminal total volatile fatty acid (VFA) concentration in TRS lambs were recorded 23.9 ml.eq/dl followed by TRS+FBS, URS and FBS. Regarding to the ruminal parameters, there were no

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**Keywords** Faba bean straw · Growing lambs · Rice straw · Urea treatment

## Introduction

The current food supply depends heavily on the livestock industry, however, regional variations apply, but globally, eggs, meat, and milk supply 15% and 31% of calories and protein per person, respectively (FAOSTAT, 2020). Grazing systems produce approximately 30% and 6% of global ruminant meat and milk production, respectively, on land that is frequently unsuitable for cropping (Herrero et al. 2013). Climate change is a major factor in agricultural productivity and is expected to have a significant impact on livestock production systems. In Egypt, the lack of feedstuffs is the most crucial limiting factor of animal production, and as a result, animals are in short supply. Egypt generates 30–35 million tons of agricultural waste per year, about 7 million tons are used as animal feed; 4 million are used under animals as organic manure. The remainder is either burned directly in the fields or used to heat small villages. These crop residues are produced after harvesting, the plant's leaves and stems are classified as plant by-products of large quantities with low protein, but it has high lignin and fiber content. After the harvest of summer crops, the problem of agricultural waste becomes very visible and aggregated (Abou Hussein and Sawan 2010). The most prevalent by-product is cereal straw, and rice straw is one of the most significant sources of roughage for ruminants in the tropics which is fed to ruminants (Wanapat et al. 2009; Khandaker et al. 2012; Su et al. 2012). Farmers in several regions of Egypt frequently burn rice straw in the field during harvest season, causing major environmental pollution on occasion. However, rice straw's poor protein and calorie value, high silica concentration, and thus low digestion limit how well it may be used. Ammonification is one of many physical, chemical, or biological treatments (Liu et al. 2002; Selim et al. 2004), urea treatment (Rahal et al. 1997; Vadiveloo and Fadel 2009), steam spray (Liu and Ørskov 2000; Weimer et al. 2003), and white rot fungal fermentation, have been used to enhance rice straw nutritional quality (Karunanandaa et al. 1995). Urea treatment raised the digestibility, palatability, and crude protein content of rice straw from 3 or 4 to 7% curd protein, which was beneficial to many farmers. In tropical conditions, urea is hydrolyzed to ammonia (Saadullah et al. 1981). In comparison to cereal straws, legume straws, such as faba bean straw (*Vicia faba*), have lower neutral detergent fiber levels and more palatable metabolizable energy concentrations. This is because they have a higher proportion of highly digestible cell contents. Furthermore, when compared to cereal straws, legume straws have a higher dry matter digestibility (López et al. 2005). Legumes straws have higher crude protein content than rice and wheat straws. Faba bean straws have higher metabolizable energy values than cereal straws in general. Pectin, which is an important component of intracellular spaces and is extensively broken down by rumen microbes, is also higher in legume straws than in grasses. Moreover, when compared to cereal straws, pulse crop leftovers (straw) contain less fiber and more digestible protein (Bogale, 2004; Tolera, 2007). However, the purpose of this study is to compare the effects of urea-treated rice straw, faba bean straw, and their mixture on digestibility, growth performance, blood parameters, and rumen fermentation in crossbred (Finland ×Ossimi) lambs.

## Materials and methods

### Animals and experimental design

Twenty crossbred male lambs ($^1/_4$ Finland × $^3/_4$ Ossimi) with an initial live body weight of (25 kg ± 1.13) 6 months of age were divided into four groups, each with five animals; all groups were fed concentrated feed mixture (CFM) at 2% of live body weight. The animals were randomly assigned to feed the following rations: URS, (as the control group) untreated rice straw; TRS, urea-treated rice straw; FBS, faba bean straw and TRS + FBS mixture of urea-treated rice straw and faba bean straw at a ratio (1:1). All the rations were isonitrogenous and isocaloric. Rice straw treated with 4% urea (w/w) and however, roughages (untreated, urea-treated rice straw or faba bean straw) were offered *ad libitum*, while CFM was offered as % of live body weight and its amount was adjusted biweekly according to change of body weight. Animals were weighed in the morning before feeding at the beginning of the trial and biweekly along trails period (120 d). The chemical composition of ingredients and rations are presented in Table 1. The experimental rations were fed to the animals in two equal portions twice daily (8.00 am and 3.00 pm) and fresh water was available at all the time. The urea-treated rice straw was ensiled in polythene sheets, and the water: urea: rice straw ratio was50:4:100 kg, according to Chenost (1996) recommendations. To properly incorporate the solution into the straw, the urea and water solution were sprayed and mixed uniformly in batches of 100 kg of straw and 4 kg of fertilizer-grade urea, and the rice-straw therapy lasted 21 days.

### Digestibility trial

Four digestion trials were conducted to evaluate the digestibility and feeding values (total digestible nutrients (TDN) and digestible crude protein (DCP)) of the experimental rations using twelve adult rams of 48 kg live body weight (three animals/ration). The experimental rations were fed to the animals in metabolic cages, and water was freely available. As described by Maynard et al. (1979), the concentrate feed mixture was offered in two portions at 9:00 a.m. and 2:00 p.m., followed by roughages. The trial period lasted 2 weeks as a preliminary period followed by 5 days as a collected period. The refusal and feces were recorded and collected at the morning samples of feed, refusal, and feces were taken and frozen until analysis and the feces oven dried at 60 °C overnight. Dried samples of feces, refusal, and feed are mixed for 5 days for chemical analysis AOAC (2007).

### Samples

After the digestibility evaluation, rumen liquor samples were taken from each animal using a stomach tube, and samples were strained using four layers of cheesecloth. Ruminal pH was immediately measured by pH meter (HANNA pH meter model HI8424). Rumen liquor samples were kept frozen at -20 °C for analysis of $NH_3$-N accordingto AOAC (2007) and total volatile fatty acids (VFA) according to Warner (1964).

### Blood parameters

The jugular vein was used to obtain blood samples according to De Palo et al. (2018), disposable needles (23G) with a negative pressure system were used to collect plasma from 9 mL tubes containing 15 USP U/mL of heparin (Vacutainer®, Becton, Dickinson CanadaInc., Oakville, Canada). Blood samples were spun in a centrifuge for 20 min at 3000 rpm. In preparation for further analysis, the plasma fraction was frozen and kept at -20 °C until examination. With the kit of commercial diagnostic tools, different chemical parameters were measured (Diamond Diagnostics, Egypt). A total protein in plasma, albumin, and globulin was computed using the differences between urea, aspartate aminotransferase (AST) and alanine aminotransferase (ALT).

### Statistical analyses

All data were analyzed using SAS (2009), general linear models' procedure, percentage data were transformed before analysis, means were separated using Duncan's multiple range test Duncan (1955) for comparison of experimental ration means when the main effects were significant to approximate normal distribution. $Y_{ij} = \mu + T_i + e_{ij}$ was the model chosen: Where: $Y_{ij}$ is the observation of ij, μ is over all mean of $Y_{ij}$, $T_i$ is effect of i(treatments), and $e_{ij}$ is the random error in the experimental.

## Results and discussion

### Feeds and rations chemical composition

Table 1 provides a summary of the chemical composition of concentrate feed mixture (CFM), straw of rice (treated and untreated with urea) and faba bean, as well as experimental rations. Crude protein was increased from 4.27% 6.98% with urea-treated rice straw, while crude fiber was decreased from 36.87 to 33.03% by same treatment. The ether extract content of rice straw was 0.97%, but these values were increased by urea treatment to 1.17%. Slight differences in chemical composition among control (URS) and evaluated rations (TRS, FBS and TRS + FBS) in organic matter, crude protein, ether extract and ash contents, and this finding agrees with Ahmed et al. (2002).

### Digestibility and nutritive value

The digestion coefficients of dry matter, organic matter and crude fiber were increased ($P < 0.05$) by urea- treated (*i.e.,* TRS) ration *versus* URS (Table 2). This finding agrees with Ahmed et al. (2002) who reported that urea-treated

**Table 1** Chemical composition[1] of the concentrated feed mixture, roughages and experimental rations (dry matter, %)

| | Dry matter | Organic matter | Crude protein | Crude fiber | Ether extract | Nitrogen free extract |
|---|---|---|---|---|---|---|
| Concentrate and roughages | | | | | | |
| Concentrate feed mixture (CFM) | 89.24 | 86.97 | 13.94 | 13.14 | 2.36 | 57.53 |
| Untreated rice straw | 86.45 | 84.27 | 4.27 | 36.87 | 0.97 | 42.16 |
| Urea-treated rice straw | 96.48 | 81.28 | 6.98 | 33.03 | 1.17 | 40.10 |
| Faba bean straw | 88.81 | 84.08 | 5.99 | 33.17 | 0.99 | 43.93 |
| Experimental rations[1] | | | | | | |
| URS | 88.19 | 85.98 | 11.48 | 21.86 | 1.85 | 50.79 |
| TRS | 91.96 | 84.73 | 11.02 | 20.97 | 1.89 | 50.85 |
| FBS | 89.08 | 85.89 | 10.78 | 20.63 | 1.85 | 52.63 |
| TRS + FBS | 90.52 | 85.30 | 10.90 | 20.80 | 1.87 | 51.73 |

[1] URS (control group), CFM + untreated rice straw; TRS, CFM + urea-treated rice straw; FBS, CFM + faba bean straw; TRS + FBS, CFM + the mixture of TRS and FBS at a ratio of 1:1. The concentrated feed mixture (CFM) was fed at 2% of lambs live body weight

**Table 2** Effect of feeding experimental lamb rations[1] on nutrient digestibility and nutritive value (%)[2]

| Item | URS | TRS | FBS | TRS + FBS | ±SE |
|---|---|---|---|---|---|
| Digestibility coefficients | | | | | |
| Dry matter | 67.40[b] | 74.22[a] | 75.72[a] | 75.05[a] | 1.18 |
| Organic matter | 70.46[b] | 76.61[a] | 77.15[a] | 78.27[a] | 0.91 |
| Crude protein | 73.69[b] | 76.58[b] | 81.15[a] | 77.32[ab] | 1.27 |
| Ether extract | 92.25[a] | 85.38[c] | 85.80[bc] | 87.90[b] | 0.71 |
| Crude fiber | 51.08[c] | 72.06[a] | 64.23[b] | 69.49[ab] | 1.64 |
| Nitrogen-free extract | 77.17[b] | 77.32[b] | 80.83[ab] | 81.42[a] | 1.11 |
| Nutritive value, % | | | | | |
| DCP | 8.46 | 9.50 | 9.88 | 9.16 | 0.12 |
| TDN | 63.65[b] | 65.28[a] | 68.11[a] | 68.70[a] | 0.68 |

[1] URS (control group), CFM + untreated rice straw; TRS, CFM + urea-treated rice straw; FBS, CFM + faba bean straw; TRS + FBS, CFM + the mixture of TRS and FBS at a ratio of 1:1. The concentrated feed mixture (CFM) was fed at 2% of lambs live body weight.

[2] DCP: digestible crude protein; TDN: total digestible nutrients. The means of the three letters a, b and c in the same raw data, differ significantly at ($P < 0.05$)

barley straw alone or in combination with soybean extract increased ($P < 0.05$) organic matter digestibility. However, the higher digestibility in the current study may be due to urea treatment expanding the cell wall, allowing cellulolytic microbes to colonize better, and improving substrate degradation from urea-treated rice straw to provide ruminal ammonia stimulated microbial protein production, the increased crude fiber digestibility (Ridla et al. 2021). Improved the dry matter, organic matter and crude protein digestibilities of FBS ration may be due to the faster degradation rate of legume straw and could also be associated with enhanced microbial growth (López et al. 2005). Increased crude protein and decreased crude fiber digestibilities for FBS ration may be also due to faba bean containing tannin that protects protein from microbial attack in the rumen (Osman et al. 1988). However, the same trend was observed with FBS and TRS + FBS rations. Nutritive values, as TDN and DCP, were slightly increased ($P < 0.05$) for TRS, FBS and TRS + FBS rations, and this may be due to the high digestibility of nutrients *versus* the control (*i.e.,* URS).

## Ruminal fermentation

The experimental rations had no effect ($P > 0.05$) on ruminal pH and VFA concentration, however, $NH_3$-N concentration was increased ($P < 0.05$) at 3 h post-feeding in TRS, FBS and TRS + FBS *versus* URS ration (Table 3). This could be attributed to rations higher crude protein content, however, ruminal $NH_3$-N concentration is a byproduct of the rumen's protein metabolism. A greater degree or speed of protein deterioration increases the concentration of $NH_3$-N in the rumen (Jayanegara et al. 2016).This finding was consistent with Highstreet et al. (2010) who found that steers fed urea-treated rice straw had higher ruminal $NH_3$-N concentration (5.4% vs. 2.5% crude protein), however, Wanapat et al. (2008) and Anantasook et al. (2013) claimed that this could be due to improved rumen ecology, digestibility and efficiency. Ruminal $NH_3$-N and VFA concentrations were increased ($P < 0.05$) at 3 h post feeding then decreased at 6 h post feeding. The highest values ($P < 0.05$) of ruminal $NH_3$-N and VFA concentrations were observed with FBS at 3 h post-feeding, and this may be due to high crude fiber digestibility.

## Blood parameters

The data of Table 4 revealed that the tested rations had no significant effect on the majority of estimated blood parameters (globulin, urea, ALT and AST). Concentrations of total proteins, albumin, and creatinine were increased ($P < 0.05$) for TRS and TRS + FBS *versus* FBS and URS lambs. The increased levels of nitrogen in the treated straw could be the cause of the considerably higher ($P < 0.05$) creatinine values for the TRS, FBS, and TRS + FBS groups. Rice straw gains more nutritional value with urea treatment because it raises the amount of crude protein and

**Table 3** The influence of experimental rations[1] on rumen parameters after 0, 3 and 6 h of feeding

| hour | URS | TRS | FBS | TRS + FBS | ± SE |
|---|---|---|---|---|---|
| pH | | | | | |
| 0 | 6.55 | 6.62 | 6.61 | 6.58 | 0.053 |
| 3 | 5.58 | 5.50 | 5.49 | 5.42 | 0.081 |
| 6 | 6.64 | 6.56 | 6.37 | 6.32 | 0.155 |
| $NH_3$-N, mg/dl | | | | | |
| 0 | 12.97 | 16.87 | 13.07 | 16.40 | 1.78 |
| 3 | 25.45[c] | 38.27[a] | 31.27[b] | 30.87[b] | 1.54 |
| 6 | 22.40 | 27.07 | 21.87 | 24.20 | 2.33 |
| VFA, ml.eq/dl | | | | | |
| 0 | 16.00 | 9.71 | 11.86 | 14.49 | 1.87 |
| 3 | 21.67 | 23.92 | 20.13 | 22.91 | 1.67 |
| 6 | 20.05 | 18.75 | 17.71 | 21.11 | 1.75 |

[1] URS (control group), CFM + untreated rice straw; TRS, CFM + urea-treated rice straw; FBS, CFM + faba bean straw; TRS + FBS, CFM + the mixture of TRS and FBS at a ratio of 1:1. The concentrated feed mixture (CFM) was fed at 2% of lambs live body weight

VFA, total volatile fatty acids

The means of the three letters a, b and c in the same raw data, differ significantly at($P < 0.05$)

**Table 4** Some biochemical concentrations and enzyme activity in the blood plasma of lambs fed experimental rations[1]

| Item | URS | TRS | FBS | TRS + FBS | ± SE |
|---|---|---|---|---|---|
| Total protein, g/dl | 7.33[c] | 7.67[a] | 7.45[b] | 7.35[c] | 0.09 |
| Albumin, g/dl | 3.48[c] | 3.84[a] | 3.62[b] | 3.55[c] | 0.21 |
| Globulin, g/dl | 3.85 | 3.83 | 3.83 | 3.80 | 0.99 |
| Creatinine, mg/dl | 1.07[c] | 1.22 | | | |

nitrogen in the straw. This increase in crude protein may explain why the animals eating the treated straw may have higher levels of creatinine. Studies have indicated that the application of urea to rice straw significantly increases its crude protein content (Al-Mwafy et al. 2020). However, dietary protein intake and plasma protein have a positive connection, the TRS and FBS groups had considerably ($P < 0.05$) higher plasma total protein and albumin than the URS lambs (Chandler et al. 1968). In general, all blood parameter estimates in this current study were within normal physiological range.

### Performance and economic effectiveness

Lambs fed TRS, FBS and TRS + FBS lambs had higher ($P < 0.05$) values of final body weight, total gain, and daily gain than URS (*i.e.,* control) lambs (Table 5), and the highest values were achieved by TRS + FBS ration. Total dry matter intake of lambs fed rations contained either urea-treated rice straw (*i.e.,* TRS, and TRS + FBS) or faba bean straw (*i.e.,* FBS) was higher ($P < 0.05$) *versus* URS ration, and this may be due to the higher content of crude protein that increased the palatability and dry matter intake. This finding agrees with Joy et al. (1996) who reported that rams fed treated barley straw consumed 15% more dry matter. Feed conversion improved for groups fed rations containing either urea-treated rice straw (TRS) or faba bean straw (FBS) compared to control (URS) ration.

Daily feed cost and relative feed cost were lower ($P < 0.05$) for TRS and TRS + FBS rations; however, TRS was approximately equal to URS. Economic efficiency and relative economic efficiency were improved by feeding rations containing urea-treated rice straw (*i.e.,* TRS) or faba bean as a sole roughage and mixed (*i.e.,* TRS + FBS) *versus* control group (*i.e.,* URS), this may be due to high final weight and daily gain (Table 5).

## Conclusions

The present study could be concluded that urea- treated rice straw could be used as sole roughage or mixed with faba bean straw (1:1) in lambs' ration to improve their performance and economic efficiency without any adversely affecting their health.

**Table 5** The growth performance, daily feed intake, feed conversion, and economic efficiency of lambs fed experimental rations[1]

| Item | URS | TRS | FBS | TRS + FBS | ±SE |
|---|---|---|---|---|---|
| Growth performance | | | | | |
| Initial body weight, kg | 25.41 | 25.27 | 25.31 | 25.25 | 0.13 |
| Final body weight, kg | 41.85[d] | 44.24[b] | 42.55[c] | 46.22[a] | 1.04 |
| Total body weight gain, kg | 16.44[d] | 18.97[b] | 17.24[c] | 20.97[a] | 0.43 |
| Daily body weight gain, g | 137.0[d] | 158.1[b] | 143.7[c] | 174.7[a] | 0.04 |
| Daily feed intake as fed, kg | | | | | |
| CFMI, kg[1] | 0.685 | 0.627 | 0.658 | 0.606 | |
| Roughage, kg | 0.444 | 0.525 | 0.502 | 0.595 | |
| Total feed intake, kg | 1.129 | 1.152 | 1.160 | 1.201 | |
| TDMI, kg[2] | 0.996 | 1.059 | 1.033 | 1.087 | |
| TDNI, kg[2] | 0.634 | 0.691 | 0.704 | 0.747 | |
| DCPI, kg[2] | 0.084 | 0.089 | 0.090 | 0.092 | |
| Feed conversion | | | | | |
| DM, kg/gain [2] | 7.27 | 6.70 | 7.19 | 6.22 | |
| TDN, kg/gain [2] | 4.63 | 4.37 | 4.90 | 5.06 | |
| DCP, kg/gain, [2] | 0.61 | 0.56 | 0.63 | 0.62 | |
| Economic efficiency, L.E./h/d | | | | | |
| Price of daily gain, L.E. | 8.22 | 9.49 | 8.62 | 10.48 | |
| Daily feed cost, L.E. | 3.78 | 3.69 | 3.81 | 3.68 | |
| Relative feed cost, % | 100.0 | 97.61 | 100.79 | 97.35 | |
| Feed cost/kg gain, L.E. | 27.59 | 23.34 | 26.51 | 21.06 | |
| Economical return, L.E. | 4.44 | 5.80 | 4.81 | 6.80 | |
| Relative economic return, | 100.0 | 130.6 | 108.3 | 153.2 | |
| Economic efficiency, L.E.[3] | 117.5 | 157.2 | 126.2 | 184.8 | |
| Relative economic efficiency, % | 100.0 | 133.8 | 107.5 | 157.3 | |

[1] URS (control group), CFM + untreated rice straw; TRS, CFM + urea-treated rice straw; FBS, CFM + faba bean straw; TRS + FBS, CFM + the mixture of TRS and FBS at a ratio of 1:1. The concentrated feed mixture (CFM) was fed at 2% of lambs live body weight

[2] CFMI: concentrated feed mixture intake; TDMI: total dry matter intake; TDNI: total digestible nutrients intake; DCPI: digestible crude protein intake; DM: dry matter; TDN: total digestible nutrients; DCP: digestible crude protein

[3] Economic efficiency (%) = economic return (L.E)/average daily feed cost (L.E). Where: prices as follows; concentrate feed mixture = 4800 L.E.\ton, faba bean straw = 1300 L.E.\ton, untreated rice straw = 1100 L.E.\ton, urea-treated rice straw = 1300 L.E.\ton and 1Kg growth = 60 L.E

The means of the three letters a, b, c and d in the same raw data, differ significantly at ($P < 0.05$)

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**Author contributions** The experiment was planned, the research was done, and the laboratory analysis was completed by AMH, HAMH, PYL, MHA, AAK, MMB, and MME. The data analysis, writing, and revision of the manuscript were completed by HAMH, and AZMS. The final manuscript was reviewed by all authors, who all concurred.

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**Data availability** Not applicable.

## Declarations

**Ethical approval** The Ethical Committee of the APRI, Agricultural Research Center, Egypt, reviewed and approved the animal study.

**Competing interests** The authors claim that there were no financial or commercial ties that might be seen as creating a conflict of interest while their search was undertaken.

## References

A.O.A.C. 2007. Official method of analysis (18th Ed.) Association of Official Analytical Chemists. Washington, D.C., U.S.A.

Abou Hussein, S.D., Sawan, O.M., 2010. The utilization of agricultural waste as one of the environmental issues in Egypt (A case study). Journal of Applied Sciences Research,6, 1116–1124.INS Inet Publication

Ahmed, S., Khan, M.J., Shahjalal, M., Islam, K.M.S., 2002. Effects of Feeding Urea and Soybean Meal-Treated Rice Straw on Digestibility of Feed Nutrients and Growth Performance of Bull Calves. Asian -Australasian Journal of Animal Sciences,15, (4), 522–527·DOI: https://doi.org/10.5713/ajas.2002.522

Al Mwafy, A. A., Behery, H. R., Saba, F. E., Gomaa, A. A. A., Khalifa, E. I., Tag Eldin, N. T. E. H., 2020. Utilization of rice straw ensiling by either solution of corn steep liquor or urea to ameliorate productive performance of dairy goats. Journal of Animal and Poultry Production, Mansoura University, 11 (2), 31–37. DO I: https://doi.org/10.21608/jappmu.2020.78853

Anantasook, N., Wanapat, M., Cherdthong, A., Gunun, P., 2013. Effect of plants containing secondary compounds with palm oil on feed intake, digestibility, microbial protein synthesis and microbial population in dairy cows. Asian-Australasian Journal of Animal Sciences, 26,820–826. doi: https://doi.org/10.5713/ajas.2012.12689.

Bogale, S., 2004. Assessment of livestock production systems and feed resource base in Sinana Dinshodistrict of Bale high lands Southeast of Oromia. Unpubl. MSc Thesis Alemaya University. Dire Dawa Ethiopia.

Chandler, P.T., McCarthy, R.D., Kesler, E.M., 1968. Effect of dietary lipid and protein on serum proteins, lipids, and glucose in the blood of dairy calves. Journal of Nutrition, 95,(3),461–468. https://academic.oup.com/jn/article/95/3/461/4779665

Chenost, M., 1996. Optimizing the use of poor quality roughage through treatments and supplementation in warm climate countries with particular emphasis on urea treatment. First electronic conference on tropical feeds with particular emphasis on urea treatment. FAO, Rome. https://www.semanticscholar.org/paper/Optimizing-the-use-of-poor-quality-roughages-and-in-Chenost/ad8ed7f0c1d1051b1dcdae7b886323ed29801d3.

De Palo, P., Maggiolino, A., Albenzio, M., Casalino, E., Neglia, G., Centoducati, G. Tateo, A., 2018. Survey of biochemical and oxidative profile in donkey foals suckled with one natural and one semi-artificial technique. PLoS ONE. 13:e0198774. doi:https://doi.org/10.1371/journal.pone.0198774

Duncan, D.B., 1955. Multiple ranges and multiple F-Test. Biometrics. II,1–42. doi:https://doi.org/10.2307/3001478

FAOSTAT,2020.Faostat.WWWDocument.URL.http://www.fao.org/faostat/en/

Herrero, M., Havlík, P., Valin, H., Notenbaert, A.N., Rufino, M.C., Thornton, P.K., Blümmel, M., Weiss, F., Grace, D., Obersteiner, M., 2013.Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. Proceedings Of the National Academy of Sciences. U.S. A110, 20888. https://doi.org/10.1073/pnas.1308149110.

Highstreet, A., Robinson, P.H., Robison, J., Garrett, J.G., 2010. Response of Holstein cows to replacing urea with a slowly rumen released urea in a diet high in soluble crude protein. *Livestock Science*, 129,179–185. doi.org/10. 1016 / j. livsci. 2010.01.022

Jayanegara, A., Dewi, S.P., Ridla, M., 2016. Nutrient content, protein fractionation and utilization of some beans as potential alternatives to soybean for ruminant feeding. Media Peternakan, 39,3,195–202.DOI: https://doi.org/10.5398/medpet.2016.39.3.195

Joy, M., Munoz, F., Alibes, X., Andueza, J.D., 1996. Effect of moisture content and addition of ureases on the effectiveness of urea treatment. ITEA-Prod. Anim. 92A,1,11–20, 34.

Karunanandaa, K., Varga, G. A., Akin, D. E., Rigsby, L. L., Royse, D. J., 1995.Botanical fractions of rice straw colonized by white-rot fungi: Changes in chemical composition and structure. Animal Feed Science and Technology, 55,179–199. https://doi.org/10.1016/0377-8401(95)00805-W

Khandaker, Z.H., Uddin, M.M., Sultana, M.S.T., Peters, K.J., 2012. Effect of supplementation of mustard oil cake on intake, digestibility and microbial protein synthesis of cattle in a straw-based diet in Bangladesh. Tropical Animal Health and Production,44,791–800. DOI:https://doi.org/10.1007/s11250-011-9969-z.

Liu, J.X., Ørskov, E.R., 2000. Cellulase treatment of untreated and steam pre-treated rice straw-effect on in vitro fermentation characteristics. Animal Feed Science and Technology,88,189–200. DOI:https://doi.org/10.1016/S0377-8401(00)00218-2

Liu, J. X., Susenbeth, A., Südekum, K.H., 2002. In vitro gas production measurements to evaluate interactions between untreated and chemically treated rice straws, grass hay, and mulberry leaves. Journal of Animal Science,80,517–24.doi:https://doi.org/10.2527/2002.802517x

López, S., Davies, D.R., Giráldez, F.J., Dhanoa, M.S., Dijkstra, J., France, J., 2005. Assessment of nutritive value of cereal and legume straws based on chemical composition and *in vitro* digestibility. Journal of the Science of Food and Agriculture, 85,1550–1557.https://doi.org/10.1002/jsfa.2136

Maynard, E. A., Looshi, J.K., Hintz, H.S., Warner, R.G., 1979. Animal Nutrition McH-B Book Co. Inc. Ny.

Osman, A.E., Ibrahim, M.M., Jones, M.A., 1988. The Role of legumes in the farming systems of the Mediterranean areas: Proceedings of a workshop on the role of legumes in the farming systems of the Mediterranean areas UNDP/ICARDA, Tunis, June 20–24, 1988 paperback- Oct.1 2011. https://www.Amazon.ca/Legumes-Farming-Systems-Mediterranean-Areas /dp/9401069492

Rahal, A., Singh, A., Singh, M., 1997.Effect of urea treatment and diet composition on, and prediction of nutritive value of rice straw of different cultivars. Animal Feed Science and Technology, 68,165–182. https://doi.org/10.1016/S0377-8401(97)00045-X

Ridla, M., Dewi, M., Laconi, E.B., Jayanegara, A., 2021. Urea treatment of rice straw: A modeling approach of its degradation kinetics in the rumen. IOP Conf. Series. Earth and Environmental Science. 788, the3rd International Conference of Animal Science and Technology 3–4 November 2020, Makassar, Indonesia 012029.doi:https://doi.org/10.1088/1755-1315/788/1/012029

Saadullah, M., Haque, M., Dolberg, F., 1981. Effectiveness of ammonification through urea in improving the feeding value of rice straw in ruminants. Tropical Animal Health and Production,6, 30–36.https://www.researchgate.net/publication/237295385

SAS version 9.2.2009. SAS for Windows, version 9.2. SAS Institute Inc, Cary, NC, USA.

Selim, A.S.M., Pan, J., Takano, T., Suzuki, T., Koike, S., Kobayashi, Y., Tanaka, K., 2004. Effect of ammonia treatment on physical strength of rice straw, distribution of straw particles and particle-associated bacteria in sheep rumen. Animal Feed Science and Technology, 115,117–128. https://doi.org/10.1016/j.anifeedsci.2004.01.011

Su, Y., Zhao, G., Wei, Z., Yan, C., Liu, S., 2012. Mutation of cellulose synthase gene improves the nutritive value of rice straw. Asian-Australas Journal of Animal Science 25,800–805. doi:https://doi.org/10.5713/ajas.2011.11409

Tolera, A., 2007. Feed resources for producing export quality meat and livestock in Ethiopia. Ethiopia Sanitary & Phytosanitary Standards and Livestock & Meat Marketing Program (SPS-LMM), Texas Agricultural Experiment Station (TAES)/ Texas A&M University System. Examples from Selected Woredas in Oromia and SNNP Regional States. Hawassa University, AddisAbaba.

Vadiveloo, J., Fadel, J.G., 2009. The response of rice straw varieties to urea treatment. Animal Feed Scirnce and Technology,151,291–298. https://doi.org/10.1016/j.anifeedsci.2009.03.003

Wanapat, M., Cherdthong, A., Pakdee, P., Wanapat, S., 2008. Manipulation of rumen ecology by dietary lemongrass (*Cymbopogon citrates* Stapf.) powder supplementation. Journal Animal Science 86, 3497–3503.https://doi.org/10.2527/jas.2008-0885

Wanapat, M., Polyorach, S., Boonnop, K., Mapato, C., Cherdthong, A., 2009. Effects of treating rice straw with urea or urea and calcium hydroxide upon intake, digestibility, rumen fermentation and milk yield of dairy cows. Livestock Science, 125,238–243. DOI:https://doi.org/10.1016/j.livsci.2009.05.001

Warner, A.C.I.,1964. Production of volatile fatty acids in the rumen methods of measurements. Nut. Abst. and Rev.34:339.

Weimer, P.J., Mertens, D.R., Ponnampalam, E., Severin, B.F., Dale, B.E., 2003. FIBEX-treated rice straw as a feed ingredient for lactating dairy cows. Animal Feed Sci. and Technol. 103,41–50.https://doi.org/10.1016/S0377-8401(02)00282-1