CHEMICAL COMPOSITION AND *IN VITRO* NEUTRAL DETERGENT FIBRE DIGESTIBILITY OF TREATED RICE STRAW SUPPLEMENTED WITH PIGEON PEA (*CAJANUS CAJAN*) HAY

Ansah, T.
University for Development Studies,
Faculty of Agriculture, Food and Consumer Sciences,
Department of Animal Science
Corresponding author: tansah@uds.edu.gh

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ABSTRACT

The study investigated the chemical composition and in vitro neutral detergent fiber (NDF) digestibility of treated rice straw supplemented with pigeon pea hay. The treated rice straw comprised fungi-treated (Pleurotus sajor-caju) rice straw (FTRS), ammonia-treated rice straw (ATRS) and untreated rice straw (UnTRS). The three treated rice straws were supplemented with or without 50% pigeon pea hay in a completely randomised design experiment. The crude protein (CP) concentration of fungi (4.4%) and ammonia (8.3%) treated rice straw appreciated relative to the untreated (2.8%) rice straw. Similarly, the treatment of rice straw influenced the NDF (FTRS [63.9%], ATRS[73.8%],UnTRS[73.4%]) and ADF(ftrs[38.6%], ATRS[41.1%] UnTRS[40.4%]) concentration. The supplementation of rice straw with pigeon pea hay reduced NDF (FTRS [54.8%], ATRS [59.4%] uNtrs [62.5%]) and and ADF (FTRS [27.4%, ATRS [13.6%] UnTRS [30.7%]) concentrations compared with the un-supplemented. In vitro dry matter true digestibility (IVDMTD) of the UnTRS was about 20% (P<0.05) less than the NH_3TRS + Pigeon pea. The neutral detergent fibre digestibility (NDFD %) was significantly lower in the UnTRS compared to the other treatments. The digestible neutral detergent fibre (dNDF %) decreased in the order of NH_3TRS + Pigeon pea < FTRS < FTRS + Pigeon pea < Sole Pigeon pea hay < UnTRS + Pigeon pea < UnTRS. The UnTRS had a significantly higher indigestible neutral detergent fibre (iNDF) than the other treatments. In conclusion, rice straw's nutrient composition and digestibility improved when treated with ammonia or fungi and supplemented with pigeon pea hay.

Keywords: *Ammonia treated rice straw, Digestible NDF, Fungi treated rice straw, NDF digestibility.*

INTRODUCTION

Globally, a crop-livestock system of agriculture is dominant in most developing countries. It is a system of agriculture intensification that relies on the synergistic relationship between plant and animal system elements to bolster critical agroecosystems processes, potentially impacting resilience to weather anomalies (Peterson *et al*., 2020; Udayakumar *et al.,* 2021). The system allows farmers the opportunity to derive benefits from both crops and livestock without necessarily increasing land area for cultivation and increasing resource use efficiency and carbon use (Udayakumar *et al.,* 2021). Efficient use of resources is achieved through crop residues and agro by-products as feed for livestock and manure from livestock for soil health improvement. Rice is one of the significant cereals cultivated in northern Ghana and the residue is normally used as feed for ruminants. It is reported that between 2008 and 2020, paddy rice production in Ghana was 302,000 MT and 987, 000 MT with a demand of about 1,450, 000 MT (MoFA, 2023). This level of rice production is expected to result in the generation of high volumes of rice straw for feeding ruminant livestock.

Rice straw is abundant within the savannah agro-ecological zone due to the extensive cultivation of rice; its utilisation as feed is limited by compounds that reduce intake and digestibility in ruminants (Malik *et al*., 2015). High levels of silica and lignin coupled with considerably low crude protein are the primary limiting factors in rice straw digestibility in ruminant animals. The organic matter digestibility of rice straw could increase by more than 8% due to ammonia treatments (Sundstøl, 1984). It has also been reported that the apparent nutrient digestibility was highest in sheep fed fungi treated rice straw and this is attributable to the ability of fungi to biologically degrade lignocellulosic into lignin, cellulose, hemicellulose, and improve CP content (Khattab *et al*., 2011; Abdel-Aziz *et al*., 2015). Thi *et al.* (2019) reported a reduction in NDF, ADF and ADL when rice straw was treated with *Pleurotus species.* Akinfemi and Ogunwole (2012) and Jafari *et al*. (2007) all reported similar results when rice straw was treated with *Pleurotus species.* Several reports have shown the benefits of rice straw treatment in enhancing nutrient composition, particularly crude protein and organic matter digestibility (Thi *et al.,* 2019; Akinfemi and Ogunwole 2012; Jafari *et al.,* 2007). Information on the effects of supplementing of treated or untreated rice straw with Pigeon pea hay within the savannah agroecological zone is limited. This study was carried out to investigate the chemical composition and *in vitro* digestibility of fungi and ammonia-treated rice straw and further examined how supplementing the treated rice straw with pigeon pea hay will affect digestibility.

MATERIALS AND METHODS

Study area

Chemical analysis and *in vitro* digestibility trial was conducted at the Forage Evaluation Unit at the Nyankpala Campus of the University for Development Studies. Nyankpala campus is located in the Tolon District of the Northern Region of Ghana within the Guinea Savanna Agro-Ecological Zone. Geographically, Nyankpala campus falls within latitude 9° 240N and longitude 0° 590W. Nyankpala is 16 km (10 miles) away from Tamale, the capital of the Northern region, with an altitude of 167 m above sea level. The study area has a mean annual rainfall of 1043 mm distributed fairly from April to late November. Temperatures generally fluctuate between 15°C (minimum) and 42°C (maximum), with a mean annual temperature of 28.5°C. The mean annual relative humidity in the is 54%.

Fungi treated rice straw

Oyster mushroom (*Pleurotus sajor-caju*) was cultivated with rice straw as substrate as described by Adam (2022). Rice straw was obtained and chopped into smaller sizes (3-5 cm) using a cutlass, after which it was washed and soaked for 12-h. It was pasteurized for about 90-m in hot water (70°C), drained, cooled and inoculated. After 30-d, the mushroom was harvested, and the rice straw was dried in an oven at 60°C for 48-h and milled (1-2 mm) for further chemical analysis.

Ammonia treated rice straw

Rice straw was obtained from the Rice field trail of the University for Development Studies and chopped to smaller sizes (5-8 cm). About 500 g of ammonia was dissolved in 100 L of water and sprayed over 100 kg of rice straw. It was then packed into transparent plastic bags and stored under anaerobic conditions for 21-days, after which it was air dried and milled (1-2 mm) for chemical analysis.

Pigeon pea hay

The pigeon pea was harvested after 100-120-day and air dried to hay. The hay was chopped and milled into smaller particle sizes (1-2 mm) for chemical analysis.

Chemical analysis

The AOAC (2000) procedure was used to determine the dry matter, crude protein (CP) and ash. NDF and ADF were determined limited of residual ash through sodium sulfite and α- amylase using the procedure of Van Soest *et al*. (1991) and this was done using Ankom^{200} fibre analyser (Method 5 for ADF and method 6 for NDF).

In vitro digestibility

The batch *in vitro* gas production technique of Theodorou *et al*. (1994) was adopted with some modifications in the source of rumen fluid (Ansah *et al*., 2016). Rumen fluid was sourced from four (4) slaughtered male Sanga cattle (300 ± 15 kg) at the Tamale abattoir. The cattle were

managed on naturally growing indigenous heterogamous pasture fields dominated with forages such as *Andropogon gayanus* Kunth., *Heteropogon contortus* (L.) Beauv. ex Roem. and Schult., *Stylosanthes hamata* (L.) Taub., *Pennisetum pedicellatum* Trin., *Boerhavia diffusa* L., *Rottboellia cochinchinensis* (Lour.) W.D.Clayton and *Cenchrus ciliaris* L (Akapali *et al.,* 2018) The rumen fluid was filtered through a double-layer cheesecloth with a continuous supply of carbon dioxide. McDoughal's buffer was prepared and kept warm in a water bath (39 °C). Treatment samples (0.45-0.55 g per bag) were weighed into the fibre filter bag, heat sealed and placed in 50 ml digestion tubes. About 30 ml of the warm and anaerobic incubation media (rumen fluid + buffer) was dispensed into the digestion tubes and incubated for 48-h in a water bath (39°C). After 48-h, the incubation process was terminated, and samples were washed in distilled water and oven dried (102°C) for 3-4 h. NDF was determined on the incubated samples using Ankom^{200} fibre analyser (Method 6) to get the residual NDF.

In vitro dry matter true digestibility (IVDMTD), Indigestible NDF, Digestible NDF and NDF digestibility were calculated using the equations below (Mertens, 2015):

IVDMTD (%DM) = 100*(DMwt – NDF_{res} / DMwt).

Indigestible NDF (iNDF) was obtained using the equation; iNDF (%DM) = 100 – IVDMTD Digestible NDF (dNDF %DM) = NDF – iNDF

NDF digestibility (NDFD %DM) = 100* dNDF/ NDF

Statistical analysis

The experiment was conducted in a completely randomised design. The one-way analysis of variance in GenStat, 11th edition was used to analyse all data. Significant difference was declared at P<0.05 and means were separated using Tukey's Post Hoc test.

RESULTS AND DISCUSSION

The results of the chemical composition of treated and untreated rice straw supplemented with or without Pigeon pea hay are shown in Table 1. The chemical composition of rice straw was significantly affected by the different treatments. The dry matter was in the range of 94 and 99% for untreated rice straw + Pigeon pea and NH_3 treated rice straw respectively. The crude protein increased from about 2% in untreated rice straw to over 10% in the treated and supplemented rice straw. The NDF and ADF declined significantly when rice straw was treated with ammonia and fungi. The ash concentration was in the range of 11.08 and 20.31% for untreated rice straw + Pigeon pea and Fungi treated rice straw, respectively.

The appreciation in protein when rice straw was treated with ammonia or fungi was expected. Both ammonia and fungi treatments have been found to cause the breakdown of the structural constituents of rice straw,

Table 1: Chemical composition of treated and untreated rice straw supplemented with or without Pigeon pea hay

Treatments	DM%	OM%	CP%	NDF%	ADF%	Ash%
Fungi treated rice straw	97.25^{a}	79.69^{c}	4.40^{e}	63.94^{b}	38.69^{a}	20.31^{a}
NH_3 treated rice straw	99.00^{a}	80.81^{c}	8.30^{d}	73.81^{a}	41.11^{a}	19.19^{a}
Untreated rice straw	96.00^{bc}	86.46^{b}	2.85^{f}	73.45^{a}	40.45^{a}	13.54^{c}
Fungi treated rice straw + Pigeon pea	95.25^{cd}	86.35^{b}	14.58^{b}	54.88^{d}	27.46^{b}	13.65^{c}
NH_3 treated rice straw + Pigeon pea	96.50^{ab}	84.20^{b}	14.75^{b}	59.41^{c}	31.69^{b}	15.80^{b}
Untreated rice straw + Pigeon pea	94.75^{d}	88.92^{a}	13.71^{c}	62.50^{bc}	30.78^{b}	11.08^{c}
Sole Pigeon pea	96.00^{bc}	90.63^{a}	24.94^{a}	52.31^{d}	22.04^{c}	9.37^{d}
S.E.D	0.298	0.439	0.1201	1.097	1.328	0.439
P. Value	<.001	<.001	<.001	<.001	<.001	<.001

$^{abcd;}$ *means with different superscript alphabets show significant difference at P<0.05.*

which ultimately makes the protein readily available (Zhang *et al.,* 2017; El Hussein *et al.,* 2015). Adding Pigeon pea hay to the treated rice straw further enhanced the crude protein content, which is attributable to the relatively higher crude protein in the pigeon pea hay than in the rice straw. The higher NDF and ADF concentration in untreated rice straw relative to the treated agrees with previous authors (Zhang *et al.,* 2020; Kumar and Gupta, 2019; Zhang *et al*., 2017; El-Husseiny *et al.,* 2015). The soaking of rice straw in an aqueous ammonia solution leads to an increase in the pH of the straw which also leads to a breakdown of cellulose and hemicellulose into simple sugars, which are more easily digestible by rumen microbes. Similarly, Fungi treatment of rice straw is responsible for lignocellulose breakdown into simple sugars.

In vitro dry matter true digestibility (IVDMTD) was significant (p=0.006) in this study as NH_3TRS had the highest mean digestibility (>80%), with the lowest obtained in UnTRS (Figure 1).

Similarly, Neutral detergent fibre digestibility (NDFD) was significantly higher in NH_3TRS supplemented with Pigeon pea hay than UnTRS (Figure 2). Digestible neutral detergent fibre (dNDF) differed among treatments in this study (Figure 3). UnTRS had the lowest with NH_3TRS recording the highest (50 Vs 20%). Indigestible Neutral detergent fibre (iNDF) was significantly higher in UnTRS with the least obtained in NH_3TRS supplemented with Pigeon pea hay (Figure 4).

In vitro true dry matter digestibility (IVTDMD) which measures the proportion of dry matter digested responded positively to the treatment with ammonia and fungi and was further enhanced when supplemented with pigeon pea hay. Both ammonia and fungi treatment has been found to increase the availability of fermentable carbohydrate owing to the breakdown of structural carbohydrates in the straw. The treatment resulted in an over 40% increase in IVDMTD compared to the untreated rice straw. Apart from the fungi and ammonia treatment, the supplemen-

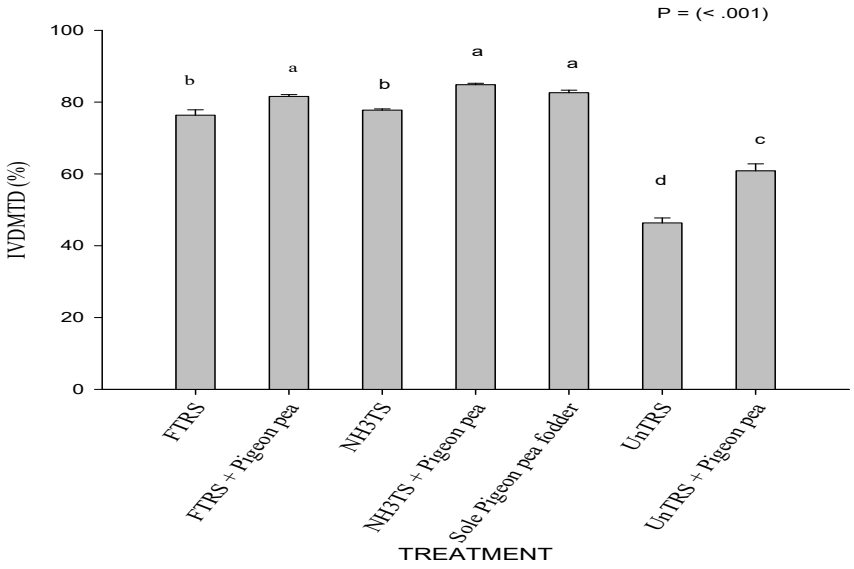

Figure 1: Mean (±SED) In vitro true dry matter digestibility of treated and untreated rice straw supplemented with or without Pigeon pea hay.

FTRS: Fungi treated rice straw; NH_3TS: Ammonia treated rice straw; UnTRS: Untreated rice straw.

tation of rice straw with pigeon pea hay was found to have contributed to the enhanced dry matter digestibility (Ahmed *et al*., 2016; Ahmed *et al*., 2015; Pandey *et al*., 2007). The increase in dry matter digestibility of rice straw supplemented with pigeon pea hay is due to the hay's comparatively low fibre content and higher nitrogen content.

The percentage of total NDF digested (NDFD) and the actual proportion of NDF fermented and utilised (dNDF) were all higher in the ammonia and fungi-treated rice straw and the pigeon pea supplemented. Digestible neutral detergent fibre (dNDF) is essential in ruminant feed evaluation. It is the fraction of the NDF fermented by rumen microbes and converted to volatile fatty acids (VFA) for energy. It has a significant effect on intake, digestibility and nutrient utilisation. In the current study, ammonia, fungi-treated rice, and rice straw supplemented with pigeon pea hay all resulted in a higher dNDF with a potential increase in intake, digestibility and nutrient utilisation when fed to ruminants.

CONCLUSION

The study concludes that the nutritive value of rice straw is significantly enhanced when treated with ammonia or fungi. Supplementation of the treated rice straw with pigeon pea hay positively influenced the digestibility and nutrient composition of the rice straw.

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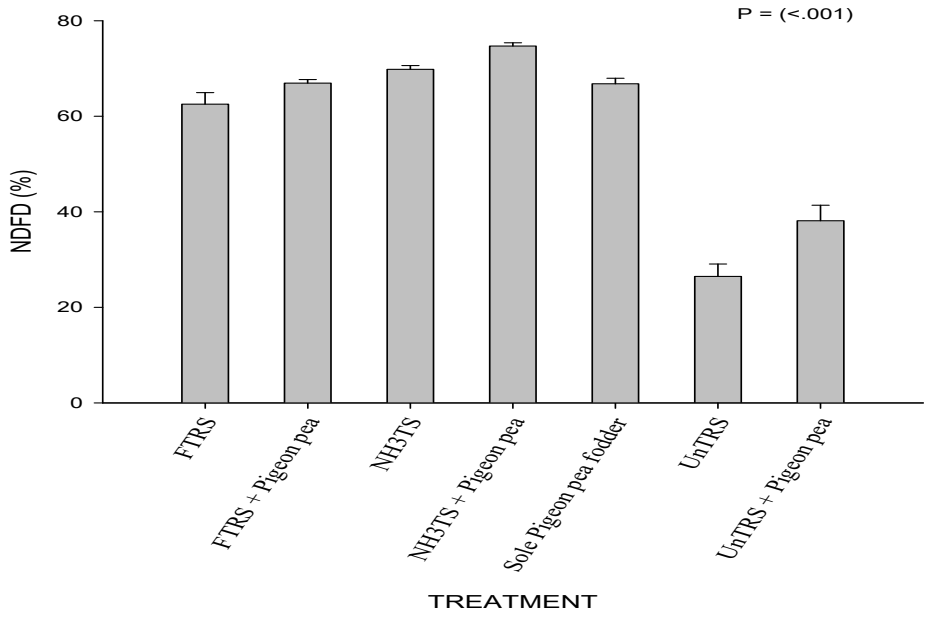

Figure 2: Mean (± SED) Neutral detergent fibre digestibility (NDFD) of treated and untreated rice straw supplemented with or without Pigeon pea hay.
FTRS: Fungi treated rice straw; NH_3TS: Ammonia treated rice straw; UnTRS: Untreated rice straw.

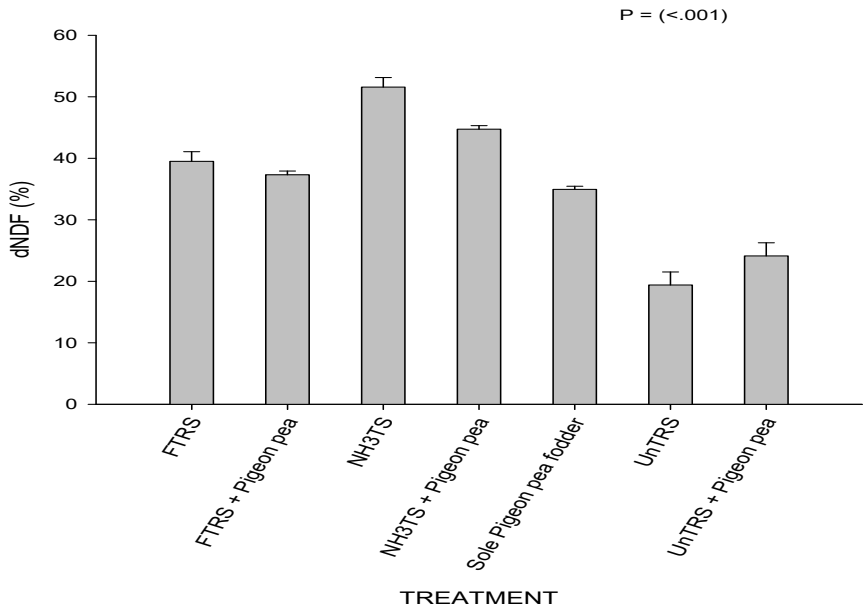

Figure 3: Digestible neutral detergent fibre (dNDF) of treated and untreated rice straw supplemented with or without Pigeon pea hay.
FTRS: Fungi treated rice straw; NH_3TS: Ammonia treated rice straw;
UnTRS: Untreated rice straw.

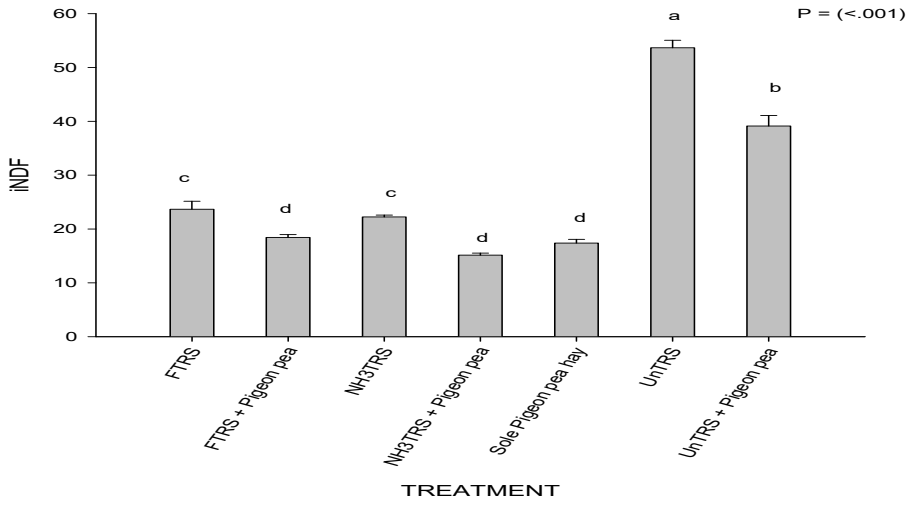

Figure 4: Indigestible neutral detergent fibre (iNDF) of treated and untreated rice straw supplemented with or without Pigeon pea hay.
FTRS: Fungi treated rice straw; NH_3TS: Ammonia treated rice straw;
UnTRS: Untreated rice straw.

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